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VAN NOSTRAND'S

ECLECTIC

ENGINEERING MAGAZINE.

NO. CXIV.—JUNE, 1878.—VOL. XVIII.

RIVER IMPROVEMENTS IN FRANCE, WITH AN ILLUSTRATED DESCRIPTION OF THE LATEST EXAMPLE OF CHANOINE'S SYSTEM OF FALLING GATES.

By Prof. WILLIAM WATSON, Ph. D., late U. S. Commissioner

III.

MODIFICATIONS OF THE LOCK AND BARRAGE AT PORT A L'ANGLAIS.

On account of the great distance, 24,600 meters, between the two barrages at Port a l'Anglais and Surrennes, one situated above and the other below Paris, and in consequence of abandoning the idea of constructing a barrage in Paris itself, the depth of the lower bay, behind the lock at Port a l'Anglais, had to be increased 1 meter, and vertical walls had to be substituted for the sloping ones. In order not to interrupt the navigation during the reconstruction of this lock, which is on the left side, a great breach was made on the right, in the over-fall, through which the traffic passed; this was afterward closed by a movable dam with gates. The old navigable pass, which had a width of 54.70 meters, has retained its gates raised by means of a boat; the over-fall, or weir, reduced to 37.90 meters, is separated from the pass by a pier 3 meters thick; the gates of the over-fall are worked from a service-bridge.

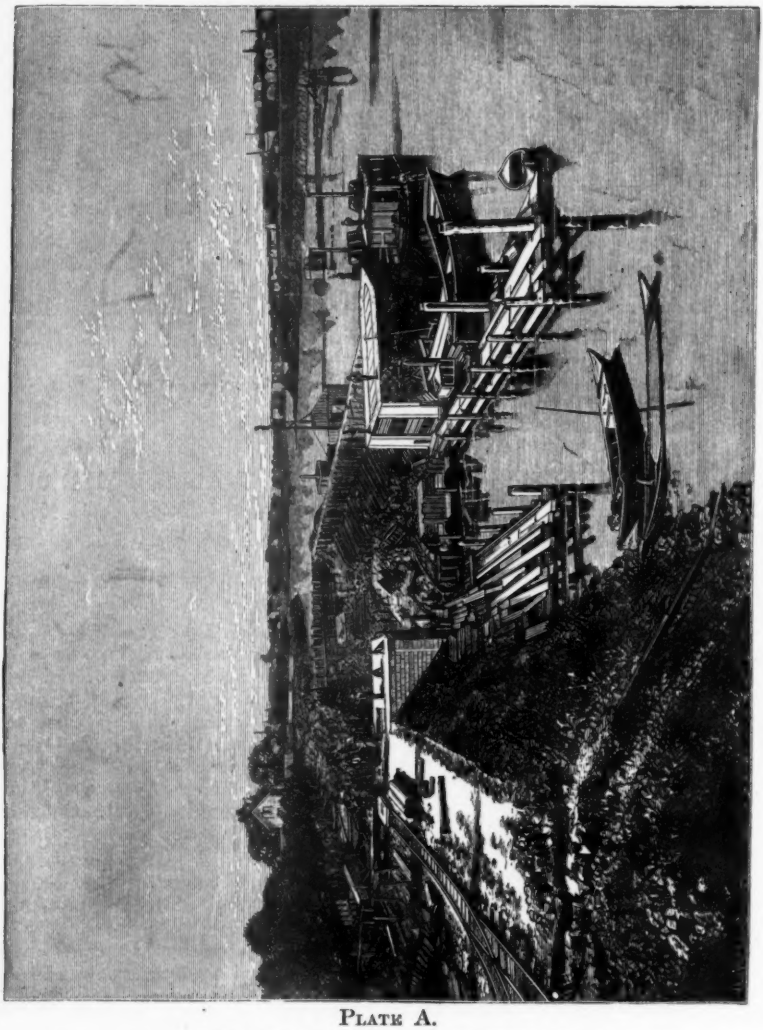
NEW PASS OR "PERTUIS NAVIGABLE."

The new pass or navigable Pertuis of the barrage at Port a l'Anglais has a clear space of 28.70 meters between the piers. It is closed by twenty-six falling gates of Chanoine's system. Its sill is 70 centimeters below that of old pass, which is closed by gates 3 meters high. The new movable gates rise to 3.70 meters above their sill. In order to support so great a head of water, changes had to be made in the models heretofore adopted by M. Chanoine. They were as follows:

1st. The width of each pannel was reduced from 1.20 meters to 1 meter, with the same interval of 10 centimeters between each pannel. The wood-work has also been simplified; it is formed of two uprights united by four transoms. The uprights are 3.86 meters long and 0.30 meter by 0.20 meter section.

2d. The inclination of the pannel to the vertical, which was 8° in the model of M. Chanoine, was made 20°, to diminish the effort tending to raise the sill from its bed.

3d. When a pannel is lowered it bears upon four cubes fixed into the platform bed; the gate is raised by two handles fixed to the uprights. By this arrangement the pannel is perfectly sustained, and no change of form in the wood-work is to be feared.



MOVABLE DAM ACROSS THE SEINE. GENERAL VIEW.

PLATE A.

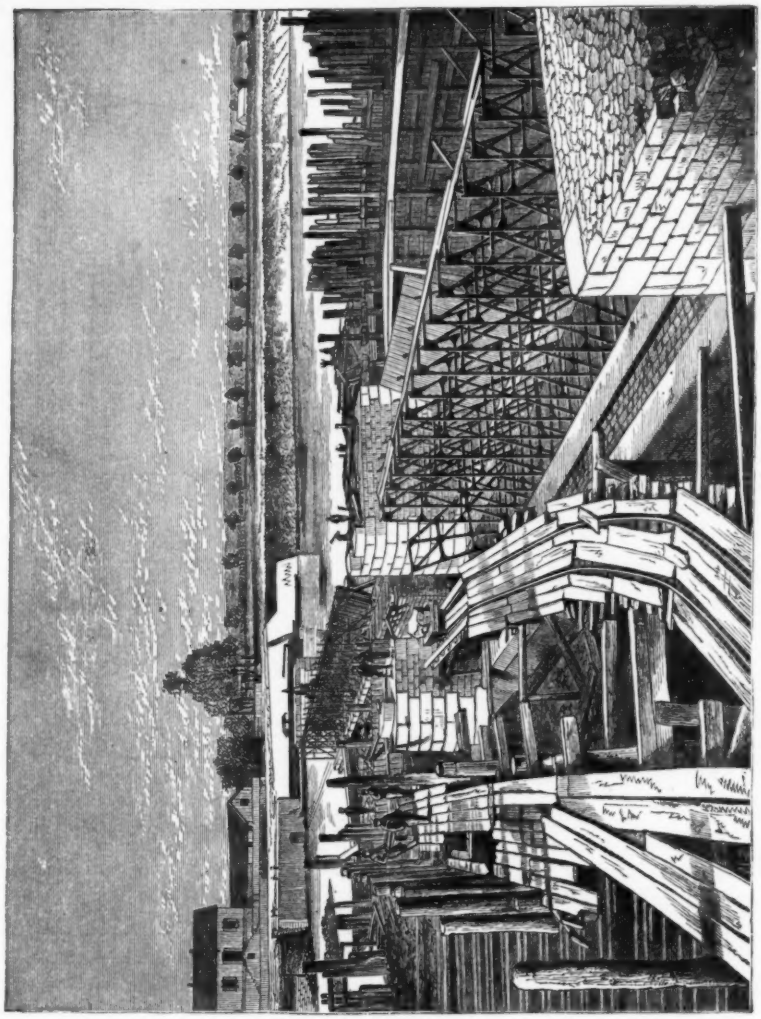
MOVABLE DAM ACROSS THE SEINE—GENERAL VIEW.

Plate A represents a general view of the movable dam across the Seine, at Port a l'Anglais, four kilometers above Paris.

The view is taken from below, looking up-stream. At the extreme right is the great breach in the weir, made to provide a channel for the traffic while the lock was being rebuilt. At the left of this breach is the weir, now reduced to a length of 37.90 meters, with its gates lowered. It is separated from the old pass by a stone pier three meters wide, situated in the middle of the river. At the left of the pier is the old pass, 54.70 meters wide; its gates are lowered, and as the sill is 1.10 meters below that of the weir, they are consequently submerged.

At the extreme left is the lock as it appeared during the process of reconstruction. This process consisted in lowering both the chamber floor and the tail miter-sill a depth of one meter, and also rebuilding the side walls.

The total length of the lock is 210 meters; its width, 16 meters, allows it to contain a double line of boats. A depth of two meters is retained upon the tail miter-sill from the next dam below, at Suresnes. The head miter-sill is unchanged, so that the lift-wall is one meter in height. At the side of the lock are seen the pile-drivers and pumping-boats used in rebuilding.



MOVABLE DAM ACROSS THE SEINE. NEW PASS, OVERFALL, AND OLD PASS

Plate B.

MOVABLE DAM AT PORT A L'ANGLAIS—NEW PASS, WEIR, AND OLD PASS.

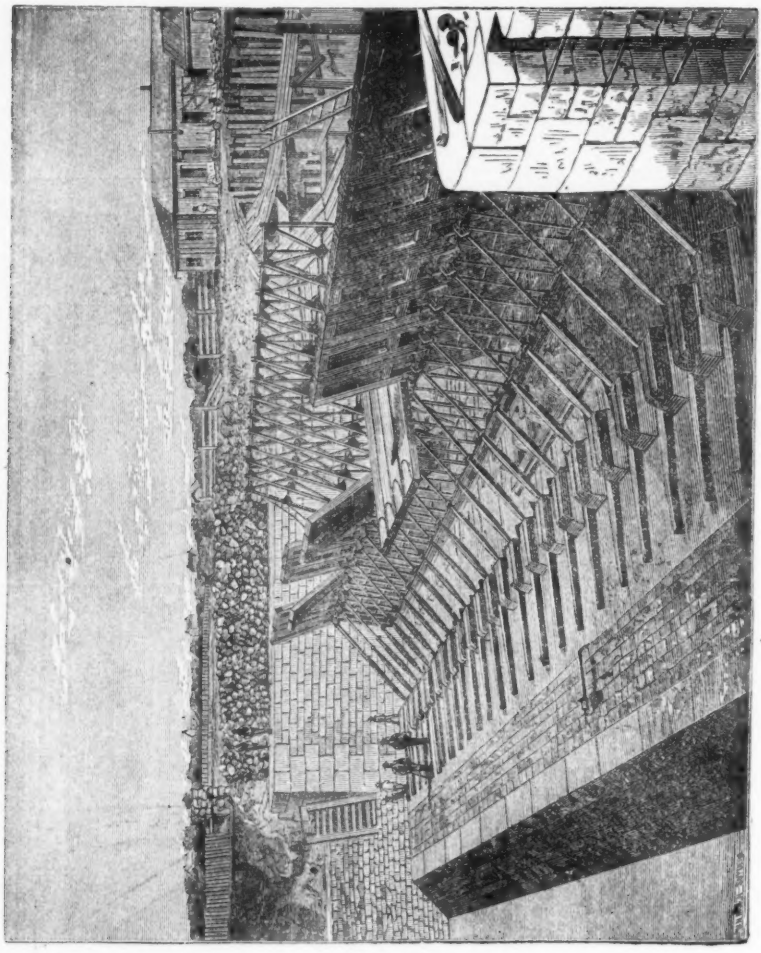
Plate B represents the movable dam at Port a l'Anglais, as seen from the shore on the right, looking down-stream.

At the right is the new pass, with its iron *fermettes* and the gates. Seventeen of the *fermettes* are erect, and the eighteenth is half raised.

At the left of the pass is the weir, with its twenty-seven automatic falling-gates. In front of these is a service-bridge, carrying a lifting-windlass. The sill of the weir is 1.80 meters above that of the pass.

At the left of the weir is the old pass; its sill is 1.10 meters below that of the weir; the gates are down; they can be raised by means of a maneuvering-boat, and lowered by a capstan and talon-bar.

Still farther to the left are the tail-walls of the lock; and beyond, the lockman's house.



MOVABLE DAM ACROSS THE SEINE. NEW PASS SEEN FROM BELOW.

PLATE C.

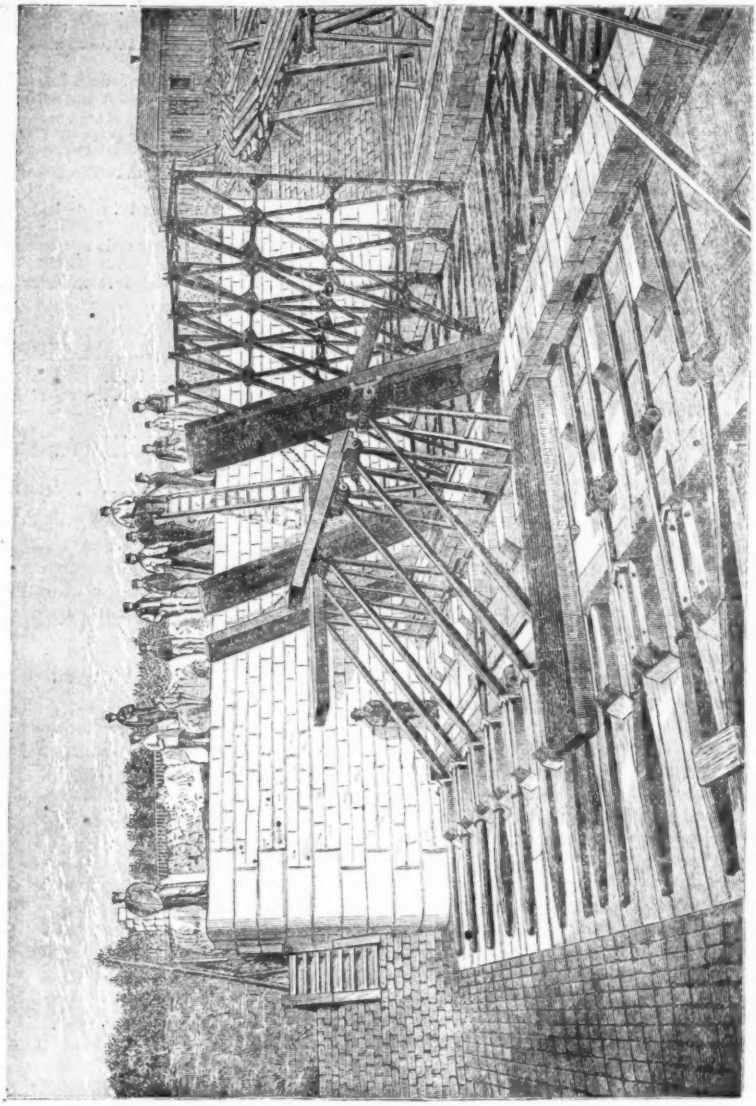
NAVIGABLE PASS AT PORT A L'ANGLAIS.

Plate C represents the new navigable pass at Port a l'Anglais, as seen from below, looking up-stream.

The opening of the pass is 28.70 meters. It has 26 gates and as many *fermettes*.

The draught on the sill in the lower bay usually exceeds 0.70 meter; that in the upper bay, maintained by the gates, is 3.70 meters; the strength of all the parts of the structure has been calculated on a supposition that a sheet of water 0.40 meter thick flowed over the tops of the pannels; that is, it has been calculated to resist a pressure due to a difference of level of 3.80 meters between the two bays.

Angle of the gate with the horizon is	80°
Angle of the abutment-prop with the horizon is	37°
	Kilograms.
Total pressure on a pannel is	9,300
Total pressure on the head of the horse	7,422
Compression of the abutment-prop	9,051
Tension on the horse	2,920
Bending moment of the pannel	2,746



MOVABLE DAM ACROSS THE SEINE. A PORTION OF THE NEW PASS AS SEEN FROM BELOW.

PLATE D.

DETAILS OF THE NAVIGABLE PASS AT PORT A L'ANGLAIS.

Plate D represents a portion of the new pass as seen from below, looking up-stream, with the gates and *fermettes* in various positions.

Horses.—Each horse is in the form of a trapezoid, 1.90 meters high, 0.76 wide at the base, 0.50 at the top. It weighs 190 kilograms. The abutment prop weighs 270 kilograms, and is calculated to resist a compressive stress of 9,000 kilograms.

Sill.—The sill is composed of three pieces: the first holds the journal-boxes of the horses; the second receives the pressure of the horses, and the third the shock of the gates when they are first raised.

Fermettes.—Each *fermette* has the form of a trapezoid, 4.75 meters high. The upper base, which supports the flooring, is 1.20 meters long; the lower base, or axle, is 3.10 long; the up-stream post is 4.80 meters high; the down-stream post is inclined at 5 vertical to 2 base, and the brace 3 vertical to 2 base.

Beside the brace, the *fermette* is stiffened by three horizontal transoms and a fourth inclined, and forming with the brace a Saint Andrew's cross. Except the lower axle, which is a cylinder 0.08 meter in diameter, each piece of the *fermette* is of U-iron, an economical arrangement, as equal weights of U-iron have a much greater transverse strength than square or even T iron, since the material is farther from the neutral axis.

The joints are easily made, and the weight per running meter is less than that employed in the construction of M. Poirée's smaller *fermettes.*

All the joints are stiffened by gussets of plate-iron 0.007 meter thick, and in addition by wrought-iron knees at the four corners of the trapezoid.

The knees of the upper angles have gudgeons, which receive the connecting rails upon which the maneuvering-windlass rolls, and also the link-catches that hold the gate chains.

Strength of the fermettes.—Each *fermette* has been arranged so as to withstand from its cap a pull from the maneuvering-chain of 3,000 kilograms at an angle of 45°.

4th. In the primitive model of M. Chanoine, the axis of rotation is placed at five-twelfths of the total height. For the new gates at Port a l'Anglais this arrangement would give to the breech a height of 1.60 meters; 1.75 meters was given to it, and the axis of rotation was placed 15 centimeters below the center of figure. This arrangement prevents these pannels from spontaneously falling, an inconvenience which was experienced in the older ones, when the water in the lower bay was very high and the falls unusually reduced. This inconvenience has actually been remedied by placing between the uprights little automatic valves, turning around a horizontal axis and having the dimensions of 100 by 42 centimeters. These butterfly-valves, as they are called, open spontaneously before the pannel falls, and the lock-man shuts them at the proper time, with great ease, by means of a boat-hook from a boat passing along behind the barrage.

5th. Instead of being satisfied with a maneuvering boat to raise the great pannels of the new pass, there has been a service-bridge established above, composed of *fermettes*, of Poirée's system, upon which the lifting-crab rolls. The *fermettes* of the bridge are 4.75 meters high, 3.10 meters wide at the base, and 1.20 meters at the top. Each *fermette* is placed exactly in front of the middle of each pannel, and the flooring of the bridge is 50 centimeters above the level of the lower bay. The uprights, the ties, and braces are formed of U iron, 8 centimeters wide, 35 millimeters high, and 7 millimeters thick.

The expense for lowering the lock at Port a l'Anglais:

	Francs.
The rebuilding of the revetment walls of the lock-chamber is...	372,056.74
Cost of the navigable pass.....	225,000.00
Total.....	597,056.74
Previous cost.....	983,675.62
Total cost.....	1,580,732.36

The interest of the cost of all of these works, together with the annual expense of repair, represents, for the mean actual traffic, 2 centimes per ton per kilometer upon the Yonne, and 1 centime upon the Seine.

COMPARISON OF WATERWAYS WITH RAILWAYS.

When we may choose between a water-line and a railway between two given points, the latter is usually less sinuous than the former, and we may admit that 1,000 feet by water are equivalent to 800 feet by rail.

Under these conditions the average price of a ton of merchandise by the two ways is as two to three—in other words, the railway augments 50 per cent. the price of transportation, but it offers in return the advantage of speed. In 1869 the freight on a ton of coal from Mons to Paris was $1.28 by water and $1.84 by rail. These prices are about in the ratio of 2 to 3 as indicated above.

The freight is about equally divided between the railway and the waterway, and we may say, as far as commerce goes, these two are equivalent, each having its advantages and its disadvantages.

Upon the most prosperous portion of the system of inland navigation, especially in the North, the activity of freight by water is comparable with that upon

the railways; it has been increasing for the last twenty years, and has effectually contested the monoply of the railways, and thus contributed largely to diminish the cost of transportation.

Finally, if we suppose the difference in the cost of transportation of one ton one mile to be one-third of a cent, applied to the 1,500,000,000 of mile tons which annually pass through the French rivers, this difference would annually amount to $5,000,000, an economy in the reduction of the price of articles of first necessity.

We must hence conclude that navigable waterways are indispensable, not only where the means of transportation are scarcely developed, but also in one which is largely served by a complete network of roads and railways.

The total tonnage on the railways is 4,000,000,000 mile tons.

These facts would have little value were it not that within a few years the improvements above mentioned have taken place in the construction of movable dams and river-gates, so as to permit, easily and with comparative little expense, rivers heretofore not navigable to be converted into canals.

ON THE STRAINS DEVELOPED IN A BEAM.

By JOHN D. CREHORE.

Written for VAN NOSTRAND'S MAGAZINE.

On page 467 of the May number of the Magazine, Professor De Volson Wood removes my suspicion "that no late authority disputes the equality of the total moments on each of the two sides of the neutral surface," by disputing it himself. Now I most cheerfully admit that his presentation of the case enables me to see that these two moments *may* be unequal, but not that they *must* be unequal; and hence the reasoning by which he infers that these moments *must* be unequal is not sound, as I will now show.

What I have to say at this time is based upon the uncorrected proof of Professor Wood's article above cited. I see no defect in the argument till we reach this sentence: "The forces producing tension tend to turn the system in the same direction as those producing compression,—in this case right-handed,—hence they have the same sign and can not be equal to each other."

Now is this impossibility of equality inferred from the sameness of signs of the two resultants of tension and compression? In a previous paragraph we find these words: "The only horizontal forces in this case are the pulls and pushes of the forces in the section. Let t be the sum of the tensile forces and c the sum of the compression forces in the section ab, then we have

$$t+c=o$$
$$\therefore\ t=-c;$$

or they must be equal and contrary."

Here we are told that the sum of the tensile forces must be equal to the sum of the compression forces, and the signs contrary; and there, when the significance of the sign has been changed, as in passing from a rectangular to a polar system, we are told that these same quantities (the sum of tensile and the sum of compression forces) "have the same sign and cannot be equal to each other." Does not likeness of sign, in the rotation system, for two horizontal forces, one above, the other below the axis of rotation, mean the same thing as contrariety of sign in the other system, for the same two horizontal forces acting in opposite directions?

The writer, then, probably means to say that these forces have the same sign and their *moments* cannot be equal to each other. For he goes on as follows: "Draw od horizontal and take e directly under P; then will oe be the arm of the force P, and od that of V. Also let T be the resultant of the tensile forces, and f its arm, and C and g the corresponding quantities for the compression ones, and we have

$$\mathrm{T}.f+\mathrm{C}.g+\mathrm{P}.oe-\mathrm{V}.od=o \quad . \quad (1)$$

The values of P and V can not both be

made to disappear at the same time from the equation, hence we cannot even have

$$T.f = -C.g$$

for equilibrium."

To this I reply, we do not require

$$T.f = -C.g$$

in the polar system, but we must always have, in this system, whether we require it or not,

$$T.f = C.g$$

whenever $f=g$; for T, the resultant of the parallel tensile forces, is equal to their sum t, and, similarly, $C=c$. But $t=\pm c$ according to the system of signs we use; therefore $T=\pm C$; and, if $f=g$, we must have

$$T.f = \pm C.g$$

according as the algebraic sign indicates direction of rotation, or horizontal direction of push or pull.

Equation (1), therefore, does not enable us to say whether $T.f=C.g$ or not. The equality of these two moments depends entirely upon the equality between f and g; that is, upon the equality of the distances of the points of application of the resultants, T and C, from the neutral axis. For C and T are axiomatically equal; that is to say, every push to the right must be balanced by an equal pull to the left, for equilibrium. And this is the axiomatic truth which I should have announced in my article published in this Magazine for August, 1877, instead of the assumption that the moments must be equal.

With Navier, and Barlow, and Kent, I was probably led to make this assumption from the analogy of the particular kind of forces under consideration to statical moments. That is, the strain on any given fiber is assumed to be equal to the strain on a fiber at the unit's distance from the neutral surface, multiplied by the distance of the given fiber from that surface. Thus each force so expressed has the form of a moment. This I offer not as an excuse, but as an explanation.

I am especially grateful to Mr. William Kent for ably instituting this discussion, and to Professor Wood for being instrumental to my perceiving that the hypothesis of Navier may not always be the correct one, even within the elastic limits.

And now what shall be said of the accordance between the formula deduced from Navier's hypothesis, and the results of a wide range of experiments upon solid rectangular beams? Simply this: The equality of the expressions, which were called moments at the instant of rupture, still subsists, but the expressions may, or may not, represent those moments.

The three expressions erroneously written in my article above referred to, viz.

$$\tfrac{1}{3}Tb(h-x)^2 = \tfrac{1}{3}Cbx^2 = \tfrac{1}{3}Bb(\tfrac{1}{2}h)^2$$

are similar functions of the ultimate resistances T, C, B, of material, to tension, to compression, and to cross-breaking; and the resulting formula

$$B = \frac{4C}{\left(1+\sqrt{\frac{C}{T}}\right)^2} \quad . \quad . \quad (2)$$

is no longer to be considered as theoretically true, except for cases where the lines of action of the resultants of tension and compression are equally distant from the neutral surface; but the formula becomes empirical, like the Hodgkinson, or the Gordon formula for pillars, and worthy of confidence according to the number of experiments by which it is satisfied.

Therefore he who publishes the results of careful experiments determining the three resistances T, C and B, for any given material, does a service similar to that rendered by Mr. Thomas D. Lovett, in reporting experiments made upon wrought iron pillars to verify the constants in the Gordon and Rankine formulas.

I have accordingly read with much interest Professor R. H. Thurston's "report on the tests of three bars of No. 2 and of three bars of No. 4 Salisbury cast iron," published in the Railroad Gazette of Nov. 30th, 1877.

His average results are:

	C	T	B
No. 2,	87,429	20,500	45,760
No. 4,	127,323	34,407	67,035

But by equation (2) we have for

No. 2, B=37,224
No. 4, B=59,580

The mean of the Hodgkinson experi-

ments on cast iron requires the B of formula (2) to be augmented by $\frac{1}{9}$ of itself. Giving our computed values of B this increment, we find for

No. 2, $\frac{1}{9}$ B=41,360

No. 4, $\frac{1}{9}$ B=66,200

Both of these values are less than the experimental numbers; and this was to be expected, since the tests for transverse resistance were made upon bars one inch square, the tests for tensile strength upon "each of the broken transverse specimens, formed into a tension specimen 0.798 inches in diameter," and the tests for resistance to compression were upon "accurately turned cylinders, each of which was two inches in length and one-half inch in diameter. They were prepared from one of the pieces taken from each bar after having been tested by transverse stress."

In the absence of any statement to the contrary, it is presumed that these inch bars, when tested for transverse strength, were as they came from the foundry, and as they would be employed in structures, with their outer "crust" unremoved,—a circumstance which may well account for the excess of the actual breaking resistance of the square bars over that computed by the formula, from tests upon the inner portion of the same metal.

IMPROVEMENT OF THE ST. JOHN'S RIVER (FLORIDA).

By Captain JAMES B. EADS.

Abstract of a Report to the Municipal Board of Jacksonville, Florida.

A personal examination of the mouth of the St. John's River, and a study of the official surveys of the bar and river, together with such other reliable data in connection therewith as I have been able to obtain, confirm the following facts:

The territory drained by the St. John's River comprises an area of about 7,500 square miles. The average rain-fall upon this area during the last twenty-seven years equals 50.27 inches at Jacksonville, and about 60 inches over the more southern portions of this area.

The mean tidal oscillations at Fort George's inlet, near the mouth of the river, are five feet and four-tenths; the highest observed tide being seven feet and one-tenth above the plane of reference, and the lowest one foot and two-tenths below that plane; the extreme range being eight feet and three-tenths.

The oscillations at Pilot Town, within the mouth of the river, and distant about three statute miles from the outer edge of the bar, are nearly one foot less. At Jacksonville the mean rise of the tide is but nine-tenths of a foot. The river is quite tortuous, the distance between the Jacksonville wharf and Pilot Town being fourteen statute miles in a direct line, while by the line of deepest water or river channel, it is twenty-four miles. The width of the river at low water immediately above Pilot Town is about 1,740 feet, and its greatest depth at mean low tide at this point, is 36 feet, its sectional area here at low water being about 36,000 square feet. This is the narrowest part of the river below Jacksonville. At Jacksonville it is about 2,000 feet wide, with a maximum depth of 12 fathoms. Its greatest widths, between these towns are at Dunn's Creek and Mill Cove, ten and thirteen miles respectively below Jacksonville. At the first place it is 2.2, and at the last, 2.8 miles wide.

The average width of the river, between Jacksonville and Pilot Town, is one mile. A mile below Pilot Town the shores of the river gradually widen out to the sea. The southern bank, a bluff one, twenty-five or thirty feet high, trends off east-southeast, or nearly at right angles to its direction opposite Pilot Town, while the northern shore, a low, marshy one, bends around to north-northeast, which general direction it follows for about a mile, when it trends quickly around to the north, its low, compact sandy beach receiving the full force of the waves of the Atlantic for a

mile beyond, at which distance the shore-line is interrupted by Fort George inlet.

About two miles and a-half by the shore-line of the river, above Pilot Town, Sister creek or inlet enters the St. John's on the north side, and by a tortuous channel about 400 feet wide, having a general direction to the north, connects the Nassau and Amelia rivers with the St. John's and furnishes an inland navigation to Fernandina for vessels of five or six feet draught during flood tide.

About midway between the St. John's and Nassau rivers, the Fort George inlet connects the Sister inlet with the Atlantic Ocean, and separates Fort George Island from Talbot Island. Both Talbot and Fort George islands are subdivided by a small inlet running north and south, by which another inland connection is made between the St. John's, Fort George inlet and Nassau River. This last-named inlet, through Fort George Island, is called Haulover Creek.

The width of the river's discharge, measured along the outer two fathom contour of the bar crest, and at right angles to the outflowing current, is nearly three miles.

The shoals which occupy the fan-shaped area, inclosed between this contour line and the expanding banks of the river, constitute the St. John's bar, and cover an area nearly three square miles in extent.

An inspection of the different surveys of the bar, and information derived from several intelligent and experienced pilots, confirm the belief that the deepest channels which have existed through the bar, have occupied, at various times, almost every part of this extensive area.

At present the river struggles to reach the sea through three well-defined channels. One of these, called on the charts the Pelican channel, lies nearly in the direction of the axis of the river volume where it leaves the plainly defined shores of the stream. This channel extends eastwardly between two large and prominent shoals, both of which are dry at half tide; one of these is called the North Shoal, and the other Pelican Reef. South of Pelican Reef, a still deeper channel is found, which follows the south shore so closely and so far around, that the St. John's River light is finally hidden by the shore from the view of a vessel passing out through it, and then the channel suddenly bends to the east and enters the ocean. This is called the south channel, and at present it is the deepest one, having at mean high tide about 10 ft. on it. Before the light-house is lost from view when in it, this channel throws off a branch to the east, called the middle channel, through which nine feet can be carried at high tide.

The material forming the bar is essentially the same which forms the sand beaches to the north of the river's mouth, the bottom through the various channels on the bar being compact, and so firm as to endanger the hulls of vessels crossing it in heavy seas by thumping the bottom of the channel. Those unfamiliar with the subject would infer from its firmness that it would yield but slowly to the action of the current, whereas no material is more sensitive to any disturbance of the equilibrium of forces which causes it to come to rest, than the sand composing such bars.

An examination of the meteorological records of the United States signal service for the past five years, for which I am indebted to Mr. Gosewisch, in charge of the office here, shows that the prevailing winds are from the northeast. The mean of the five years being 7.2 months during which the wind was from the north or northeast. We may therefore reasonably infer that the prevailing littoral, or shore current of the sea, flows southward in front of the river's mouth during the same period of time.

The height and protrusion of the southern bank of the river into the sea would indicate the presence of a current to the south during most of the year, for the general tendency of all silt, or sediment-bearing streams entering the sea at right angles to prevailing sea currents, is to have their mouths turned around towards such currents as though opposing them.

This is because the sedimentary matters discharged by the stream are carried by the sea currents across the mouth of the stream, and deposited on the shore beyond. The constant accumulation of earthy matters on that side causes that bank to grow more rapidly out into the sea than the other, and as these matters continue to accumulate upon it, the

course of the river is gradually forced around, by the deposits on that bank, into a direction apparently in antagonism with the sea current.

During the greater part of the remaining four months and a fraction, it is quite likely that the sea current runs in the opposite direction, or to the north, as the wind is during those months chiefly from the southeast or south.

As the St. John's carries but little sediment to the sea, the bar, at its mouth, is of the kind known as drift bars, a term used to distinguish them from those formed by alluvious or river deposits at the mouth of delta rivers, such as the Mississippi, the Danube, the Dwina, the Rhone, etc.

Over the profounder depths of the ocean the water constituting the waves simply rises and falls vertically, like the material of a carpet when spread out horizontally, and shaken by men standing around it. The waves move horizontally, one after the other, but little or no horizontal motion of the water occurs as a result of the progress of the waves alone.

But the case is quite different when the water in its vertical descent feels the resistance of the sloping bottom of the shore. A horizontal motion in the water is then produced, slight at first, where the shore is deep, but increasing as the depth diminishes, and always moving shoreward. As the waves increase in height the horizontal motion becomes so swift in depths of from one to three fathoms, that the water of the advancing wave-crest rushes rapidly forward and falls over the water in the trough before it, and thus forms what are termed breakers.

Observations of tidal waves have established the fact that the velocity of such waves is greatly influenced by the depths over which they pass. In fifty fathoms the velocity is about sixty miles per hour, while in 5,000 fathoms it is about 528 miles. The waves produced by the winds are similarly affected by depth. Their velocity is, consequently, arrested as they approach the shore. Those nearest the beach are overtaken by those which follow, and which are in deeper water, and overwhelming at recurring intervals, those in advance of them increase the height of the breakers in rythmical periods.

The shoreward or horizontal motion imparted to the water is called translatory motion, and the rapidity and distance to which the ocean-swells are driven out upon its sloping beaches illustrate its action. Consequently, wave-action in shallow depths near the coast has a constant tendency to sweep up the sands in such depths and deposit them on the shore. Under the operations of these almost incessant forces, which are heaping up the sands on the shore, and the opposing influence of gravity inclining them to run back again, the beach assumes a certain inclination or slope, which is called the angle of repose. This angle is altered when the wave force, creating the motion of translation, is intensified by storms, and it is steeper or flatter according to the character of the material brought shoreward by the waves. Shingle and course sand assume steeper slopes than quicksand, which is composed of rounded particles, and that which is left above the mean range of the tide is steeper than that which is constantly submerged. The more violent are the waves, the greater will be the depths from which sand, shells, loose stones, etc., will be swept up, by this motion of translation, on to the shore.

From this it is evident that every river emptying into the sea, unless under exceptional conditions, must struggle through the sands that are thrown up shoreward by the waves. These, in reality, are continually striving to barricade the river current and prevent it from entering the sea. In the contest, the river forces, under the ever-varying intensity of hydrostatic pressures resulting from freshets and tides, are as constantly sweeping down the sandy barriers thrown up by the waves, and, seeking out the lines of least resistance, the river flows through continually shifting channels across the bar.

In this external warfare of opposing forces, the sands at the river's mouth are driven first in one direction and then in another; at one time by the tides at another by the river, and again by the waves over the whole area of the bar, constantly extending it into the sea, by

the accumulations of the river sediment and the ocean sands, until it is built out so far seaward that its further growth is retarded or stopped altogether, either by the currents of the sea, or by the steepness of the shore line, or by both causes combined.

It must be evident from this simple explanation, that the extent of the shoreward movement of the sands caused by wave action, is increased by the height of the waves, and that it decreases with an increase of depth.

The sands in four or five fathoms of water are but little disturbed by wave action, except in storms, although even large stones have been moved by the waves of very violent storms in much deeper water.

If the discharge of a river in a tideless sea requires a certain width and depth of channel for its accommodation, and the natural cross section be too wide and shallow, we may safely assume that if the width be reduced by compelling the water to flow through artificial banks, such as jetties or piers, the depth will be proportionately increased in the narrowed channel between the jetties. If the volume be so great as to give a depth of twenty feet between the jetties, we may safely assume that none but storm waves will have power to move the sands on the ocean's bed in front of the channel; while the river-current, being thus concentrated, would be more potent to repel the advancing current induced by the waves and thus neutralize its effects. As storms are of brief duration, while the outflow of the river is more or less constant, it is plain that such jettied channel would maintain such depth as the volume of the river demanded, almost if not wholly irrespective of the effects of the translatory action of the waves. It must likewise be evident that the deeper the channel between the jetties, the less liable will it be to even a temporary diminution in depth from the effect of storms.

This only supposes such artificial contraction of width is made to the mouth of a river discharging in a tideless sea, and having sufficient volume of discharge to maintain a depth of twenty feet or more through a jettical channel of the requisite width.

Let us suppose that jetties be applied to the St. John's, and assume, for the time being, that no fresh water at all is discharged by the river into the sea. We will, then, have the conditions reversed; that is, we will have no river discharge, and we will have a mean rise and fall of tide equal to five and a half feet. Leaving out of consideration the magnificent lacustrine river above Jacksonville, we find extending from Jacksonville to the sea, a river basin twenty-five miles long, and averaging one mile in width. At one end of this basin the average rise of the tide is nearly one foot and at the other end five and a half feet. The average quantity of tidal water passing into and out of this basin twice a day, is therefore equal to nearly 2,000,000,000 cubic feet. This would produce an average rate of current equal to two miles per hour, through a channel having a cross-section of 30,000 square feet, or a maximum current during average flood and ebb-tides of about four miles an hour.

With such a tidal basin, *even without the additional advantage of the river current*, resulting from a large annual rainfall upon 7,500 square miles drained by it, I should have no hesitation in recommending the application of parallel jetties at the mouth of the St. John's river, as a certain means of permanently deepening the channel through the bar at its mouth. Every inlet into the sounds or tidal basins which border the eastern sea coast of the United States, is an evidence of the ability of the ebb and flow of the tides to maintain a depth of channel from the ocean into these basins, and to resist the influence of the wave-action, which would otherwise soon shut off these basins from all connection with the sea. The depth of these channels is determined by the volume of tide water forced through them in filling and emptying the different basins into which they lead, and by the width of the inlet. If the latter be artificially contracted, the depth of the channel will be increased and the quantity of water received and discharged by the basin will be greater, because the flow of water is retarded by the friction caused by its contact with the bed of the channel. If the channel be narrowed and deepened, the frictional surface will be lessened and the basin will fill faster. The friction that must

be overcome by the water in passing in during flood tide over the great expanse of the St. John's bar causes the tide to rise one foot less in height inside the bar at Pilot Town, than it is outside of it at Fort George inlet. Hence, if jetties were applied to reduce the width of the inflowing waters, now nearly three miles wide, and they were caused to pass through a channel only three or four-tenths of a mile wide, the frictional resistance would be greatly decreased, and higher tidal oscillations would occur at Jacksonville. The river channel would, therefore, not only be deepened over the shoals in the river by a higher plane of water at high tide, but the increased flow of tidal waters through the river would deepen the bottom likewise and materially improve the navigation of the river.

The size of the river at Pilot Town immediately above the bar, where it is exceptionally narrow, furnishes more reliable means of determining the width and depth of channel that can be maintained across the bar with the desired depth between parallel works, than any mathematical formulas, relating to the flow of water; for there are so many influences which patient experimental investigation would fail to correctly estimate, tending to modify the results of any strictly technical solution of the question, that such method would be unreliable. The bends of the river, the width of its bed, the irregularity in the flow of the tides, and the difficulty of determining the varying volume of the river's discharge, all influence the result, and all conspire to maintain the size of the channel at the point referred to. At this point we find that by the combined influence of the tides and fluvial discharge, the currents maintain a section 1,740 feet in width, with a maximum depth of thirty-six feet, the area of the section at half tide being 36,000 square feet. This maximum depth could not be secured at the sea ends of the jetties with the width found at this point, for the reason that under the influence of the waves of the ocean, the bottom of the channel there would assume a flatter shape than in the river.

The width of the channel to be determined through the jetties should not only be considered with reference to commercial requirements, and to the amount of water to be discharged through it by the combined volume of the river and the tides, but also with reference to the cost of construction and maintenance of the works, for these will be more expensive in proportion as the channel is deeper, and the channel will be deeper in proportion as it is contracted by the jetties, within certain limits.

The width found at Pilot Town, say 1,700 feet, is sufficient to secure a judicious mean between the probable demands of commerce, and an economic expenditure for construction and maintenance. This width I feel confident will produce a reliable channel of, at least, twenty feet in depth at average flood tide. The depth will more probably be twenty-three or twenty-four feet, through jetties placed at that width.

The most judicious location for the jetties can only be determined by a careful survey, which survey, owing to the shifting nature of the channel through the bar, should be made immediately before commencing the work. A permanent artificial channel can be made through almost any part of the bar, but the location which will produce the best results for the least expenditure, can only be determined after such survey as I have suggested. The direction of the jetties' channel should be such as to furnish the longest straight line of current into the river, as the in-flow of the tide will be diminished by bends in the channel. Its discharge should be as nearly at right angles to the littoral currents as may be practicable with the desired straightness of inflow. On the accompanying chart I have indicated such alignment of the works as I have deemed most judicious for the conditions shown by it. It is possible that a survey immediately preceding the construction of the jetties may show no important difference in the form of the bar, and in such event I would make no alteration in the location shown on the chart.

The mode of construction should be similar to that used at South Pass. Although willows cannot be conveniently obtained in the vicinity, other materials are at hand in abundance with which to construct brush mattresses for the work. Palmetto piles can likewise be abundantly obtained, and as these are not attacked

by the toredo, they can be advantageously used to lessen the amount of stone that would otherwise be required.

When the construction of the works is begun the foundation courses of mattress for both jetties should be laid, from the land to the sea end of the jetties, before any portion of the work is built up to its full height. The height of the jetties should be at least two feet above mean high tide.

I have made an estimate of the total cost of the proposed works, which is based upon the most reliable data I have been able to obtain. While the cost may be considerably modified by the results of subsequent surveys, and by the skill and experience of the engineer who may be charged with the execution of the works, and while the estimate necessarily only approximates, it will be found sufficiently accurate and reliable to base legislative action upon, and sufficiently liberal to insure the execution of the work by competent persons, for the sum named. A more exact estimate can only follow a careful and thorough survey and the preparation of detail drawing. The estimate embraces the following materials in place in the works, which are necessary to complete the jetties, two feet above high tide, from each shore of the river to the fifteen-foot contour curve on the outer face of the bar. It includes fifty per cent. for settlement and contingencies. The total length of the two jetties will be three and one-half miles:

ESTIMATE.

425,000 cubic yards of mattress-work, $2.25	$956,250
90,000 cubic yards of stone ballast and riprap, $6.00	540,000
864,000 linear feet of piling, 20 cts.	172,800
240,000 feet, board meas. of lumber, $20.00	48,000
	$1,717,050

The mattress foundations of the sea-ends of the jetties are 250 feet wide, and a similar width is deemed necessary in the line of the south jetty where it crosses the south channel near the main shore.

I have not deemed it necessary to make an instrumental survey of the bar, as it would involve considerable time and expense.

The surveys I have consulted are as follows:

1st. A Spanish chart, by Mariano de la Rocque, 1771.

2d. A comparative chart of surveys, by Lieut. T. A. Cravin, U. S. N., asst. 1853, and S. D. Trenchard, U. S. N., asst. United States Coast Survey 1857.

3d. United States Coast Survey preliminary chart, 1856.

4th. Sketch of the bar, February, 1873, furnished by the United States Lighthouse Board.

5th. Sketch of the bar, February, 1874, furnished by the United States Lighthouse Board.

6th. United States Coast Survey chart of St. John's River, 1878.

I am much indebted to Dr. A. S. Baldwin, for valuable and pertinent information, and for the loan of several instructive charts, reports and books relating to the problem under consideration. This gentleman has given many years to the study of the subject, and has brought to the investigation of it a large amount of scientific research aided by close observation of the phenomena presented.

I give in his own brief language what he deems the chief cause of the shifting channels across the bar, and the reason of the river discharge being unable to maintain a single channel of greater depth and stability. Dr. Baldwin says:

"Owing to their proximity, difference in volume of water, and sources of supply of the respective streams, there is an interchange of water between the St. John's River and Fort George inlet, producing cross currents, quite detrimental to the free and normal discharge of the waters of the river, through a direct and unshifting channel to the sea. To remedy this condition of things, the cause of abnormal action must be removed.

"The closure of Fort George inlet, or the diversion of its waters through Haul-over Creek, enlarged so as to give passage to them into the river above its bar, so as to cause a commingling of the waters of both streams inside of the bar, instead of an interchange outside, has appeared to me to promise a successful result by removing the cause of cross currents which now interrupt navigation and interfere with the free discharge of the river over the bar.

"The momentum of force of current due to its large volume will enable the

river to open and maintain a channel sufficient for all present or prospective wants of commerce, provided this water can be kept in a concentrated stream, and my opinion has been that if the deflecting influences of the inlet could be removed, the stream then, would not be so liable as now, to be divided into numerous channels; but the waters would then be disposed to concentrate into one stream, having sufficient power to sweep out of its pathway all obstructions to its free passage to the sea, without assistance from artificial appliances to either side of the channel, because I have attributed to the cross current or see-saw-ing notion of waters across the north shoals, between the river and inlet at different times of tide, a prominent part, and the principal instrumentality in shifting the banks of sand and preventing the river from having any permanent and well-defined channel."

The deep water in front of the beach seen on United States coast survey charts, between the mouth of the river and the inlet, shows the existence of such interchange of waters as Dr. Baldwin refers to, as a result of the difference in time of the tide action in the inlet and the river; and I think it is quite possible that some improvement of the bar channel might have resulted from the carrying out of his suggestions, but not sufficient to meet the wants of commerce. It is, however, very evident that a line of works nearly one and three quarter miles long, transverse to such currents as may be due to the cause assigned, would completely interrupt them and prevent their evil effects.

In addition to the plan of improvement recommended by Dr. Baldwin, Lieutenant (now general) H. G. Wright, United States engineer, recommended in 1853 the construction of a single pier on the north side of the channel. The length and proposed location of this pier I have no information about. Single piers have been applied to drift bars in tidal and non-tidal waters with benefit, but the superior advantage of protecting the channel by parallel piers or jetties has been so abundantly demonstrated within the last twenty-five years as to leave no question about the propriety of applying them in this case. They have been applied at the mouths of many rivers on the Baltic and the European coast and on the upper lakes, with marked success. The engineers who oppose the jetty system of improvement at the present day, I believe, have confined their objections to its use, entirely to delta forming rivers, and have based their predictions of its failure at the south pass, on the fact that the Mississippi discharges an immense amount of sedimentary matter, which they asserted would cause a rapid re-formation of the bar, immediately in advance of the jetties. This conviction on their part was strengthened by the belief that no littoral current existed there to sweep away this large discharge of sediment. They claimed that the great success of the system was due to the fact that the rivers whose bars had been deepened, were comparatively free of sediment, and that the outer face of the bar was swept by a littoral current. As both of these conditions exist at the St. John's bar, the recommendation herein made to improve it by jetties will doubtless be cordially endorsed by them; while it cannot, I am sure, fail to meet the approval of those engineers who advocated their application to the bar at the mouth of the Mississippi. Their success there, has only confirmed the fact that the system is equally applicable to either delta, or drift bars. The present Chief of Engineers United States Army declared, in 1875 in his annual report, that the jetty system had never been applied to the bar of but one delta-forming river (the Rhone), and that it had been a failure there. This has been publicly declared to be a mistake by Col. W. Milnor Roberts, C. E., who visited the mouth of the Rhone for the express purpose of examining into this very question. He was accompanied by several of the members of the United States commission of engineers, who afterwards reported, in 1875, in favor of applying the system at the mouth of the Mississippi, Col. Roberts has stated the fact, which I and other engineers, who have visited the mouth of the Rhone well know, namely, that the jetty system never was applied there at all. Dykes were built in the river mouth to close several latteral outlets and cause the river to discharge through

one mouth only, but these dykes were never extended out into the sea over the bar to deep water, as is proposed for this bar, and as was done at the south pass, at the Danube, the Dwina, and the Maas, all of which are delta-forming rivers. The dykes at the Rhone were never nearer than seven-eights of a mile from the crest of the bar.

To confound anyone who still persists in declaring that the jetty system failed at the Rhone, it is only necessary to ask him to point out among all of the many successful applications of the system, one single instance where the jetties are not built out in the sea across the bar to the deep water beyond, and then ask him to state if those at the Rhone were ever built out on to the bar at all.

As the jetties at the ship canal at Amsterdam and those at the Maas, besides innumerable others on the Atlantic, have proved their ability to withstand the severest ocean storms, it is scarcely necessary for me to advance any arguments to show that the proposed works can also be made thoroughly permanent.

The importance of improving the St. John's bar as a matter of national interest will scarcely be questioned in view of the advantages it offers as a naval station on our south Atlantic coast, and as a harbor of refuge.

The delightful climate of Florida, the ease with which many semi-tropical and remunerative products are reared, such as sugar-cane and cotton, and its adaptability to the production of oranges, lemons, figs, dates, bananas, peaches and berries of the finest qualities, is rapidly attracting an industrious and energetic population. It's vast forests already furnish important shipments of lumber, tar, pitch, turpentine and resin, and its gardens furnish to the north large quantities of vegetables, melons, etc.

Notwithstanding the immense disadvantage of the bar at the mouth of the St. John's, the shipments of lumber in 1877, from Jacksonville, amounted to 40,000,000 feet, on which a freight was paid $1 per 1,000 higher than on that shipped from Brunswick and Fernandina. In this one item alone it will be seen that the bar has cost $40,000 per annum in extra freights. The vessels leaving port are frequently detained for days, and even weeks, at the bar, waiting for favorable tides and deeper water, at a large aggregate cost for demurrage. This is estimated, by intelligent and well informed parties, to cost the commerce of the St. John's not less than $100,000 additional per annum.

In consequence of the delays at the bar the clearances at the custom-house, at Jacksonville, have steadily declined from 80,798 tons, in 1873, to 39,681 tons in 1877.

The river tonnage consists of thirty steamers, navigating about 400 miles of the St. John's river, and its branches.

For these interesting statistics I am indebted to Mr. M. W. Drew, of Jacksonville.

THE APPRENTICE IN THE PATTERN SHOP.

By GRAHAM SMITH, Past President of the Liverpool Engineering Society.

When it is considered that no engineer or architect is properly qualified to design cast-iron structures without having a definite idea of the manner in which patterns are constructed and castings made we feel that it is unnecessary to apologise for introducing this subject to our readers. This craft rightly takes a high position among the trades. To be a good pattern-maker demands no ordinary degree of intelligence, the power of skillfully handling tools, and work both of a manual and mental nature. It behoves young men therefore on entering the pattern-shop to respect and appreciate at their proper worth the men following this calling. So far as work is concerned the articled pupil or ordinary apprentice ought to make himself subservient to the foremen and journeymen with whom he may come in contact.

On entering the shop the new apprentice as a rule will be placed under one of the best men and expected to work in

accordance with his direction. It is to the interest of the pupil to do all in his power to command the respect of this man, whom it must be remembered is paid by his employers to do his day's work and not to teach the apprentice. The latter must therefore make up to him by his services for any loss of time which may be occasioned in teaching him how to handle his tools, and how to become generally acquainted with the routine of work. This is necessary in order that the journeyman may show as good a day's work as other men who are unburdened by the charge of an apprentice. There are many little duties which done spontaneously tend to harmonize the relationship existing between journeyman and apprentice and which with a little watchfulness and tact may be performed in a most gracious manner. Screws, nails, or sand-paper may be required from the stores, or the glue-pot may require reheating. These and numberless other matters of a like nature should be watched for and performed with alacrity and good-will. It is useless for the apprentice to pretend that he is above these minor duties, for as a matter of fact it will be some little time before he is fit to perform others of more importance. He may rely upon it that as soon as he is competent to do work requiring skill and care, the journeyman will not fail to avail himself of his more developed capacities and find some other means of getting his screws or nails. It is to the latter's interest to do so, for if the work is being performed by the "piece," his money-earnings will be larger, or if as is more often the case, he be working "day-work" he will make a greater show for his time by employing his apprentice to the best advantage. The apprentice will not only be indebted for his teaching but he will often require the use of tools which it would be out of the question for him to purchase. A pattern maker's tools are his idols, and one of the first duties the tyro must learn is to return all tools to their owners properly sharpened and ready for immediate use, and above all things he should be careful not to leave them kicking about his bench after having made use of them. A good workman always keeps his tools sharp and otherwise in a proper condition.

A few pounds judiciously expended will purchase the tools that an apprentice is likely to require, but of course if he purposes to become a journeyman, he must add to this stock from time to time, and as not unfrequently happens it may become in time a most valuable collection. The following will possibly be found sufficient for any one who purposes remaining but ten or twelve months at this class of work:—1 cross-cut saw rather widely set so as to be useful for all purposes, 1 tenon saw, 1 trying plane, 1 jack-plane, 1 smoothing or hand-plane, 1 rabbit plane, 1 spokeshave, 1 set of chisels, 1 set of inside and outside gouges, 1 two-foot rule, 1 oil-can, an oil-stone for sharpening his flat tools, and two or three finger-slips for gouges, a pair of tradesman's compasses, inside and outside callipers, and one or two squares. The turning tools he may for the most part manufacture by grinding down old files. There are other tools of a more costly nature the use of which he will frequently require, such as a brace and bits and "hollows and rounds" for working rounds and fillets, but if he ingratiate himself by becoming and gentlemanly behavior into favor with the men he will experience no difficulty in borrowing these whenever he may wish to do so.

The apprentice should early learn not to be disheartened by failures. It is only natural that after six months he should turn out very rough work when compared with that of the journeyman of six or sixteen years. He should endeavor, however, to make his work as nearly perfection as his abilities will allow, and should on no account try to polish up bad work with sand-paper, or to cover up its imperfections with putty or paint. A good workman seldom employs sand-paper, except when stretched over a cork just to give a finishing touch to the various portions of the pattern before fixing them in place. Under any circumstances it should be used sparingly, and only after the work has been properly shaped with the edge tools. Nothing looks more slovenly than to see ill-finished work sand-papered and puttied. The apprentice before actually commencing to make patterns must thoroughly understand and have a just conception of the manner of putting the patterns in the sand and getting them out again. On starting to make a pat-

tern his first question to himself will then be, how will it be best to mould this? And the answer much governs the form the pattern should take. It requires great care on the part of the pattern-maker in selecting the proper course, as after the pattern is made the moulder seldom has any choice in the matter.

It is quite impossible here to describe the method of proceeding with complicated forms, but it may nevertheless be well to say something of a simple example, and from it endeavor to point out how to proceed with those of a more intricate nature. Let the example be a simple round cylinder with a hole through its center. It is at once evident that were it not for the hole the pattern might be cast by employing two boxes and making the parting in the sand so as to divide the cylinder into two equal portions, thus leaving an impression of half the pattern in each box. The hole through its center cannot be moulded in this manner. This brings us to the consideration of the question of "cores." Two small circular pieces termed "prints" are placed on the pattern in the position of the extremities of the required hole. These leave their impression in the sand so that a core may be laid in. A core consists of sand moulded to the required shape of the hole, so that on putting the boxes together we have the hollow cylindrical mould with a core of sand running through its center of a diameter corresponding to that of the required hole. The metal being run in and the casting cooled down, it is only necessary to knock out the core of sand and the cylinder is complete with the hole through its center. This is the simple principle on which the most complicated forms are obtained. The interior of a locomotive cylinder and the intricate steam and exhaust ports are taken out in much the same manner as that just described. Small cores are usually made in boxes of wood in which the sand is moulded to the required form and then baked in an oven specially constructed in every foundry for this purpose. Large cores are made in various other ways but these must be seen to be understood. The apprentice will do well to devote any spare time he may have to watching closely foundry operations. He will then become conversant with the practice of this department and learn to make his patterns so that they may be easily removed from the sand.

In making patterns the drawings must not be followed implicitly. Sufficient "draw" must always be put on to enable the patterns to be got out of the sand. Slightly over one-sixteenth of an inch in a foot is generally sufficient for this purpose, but when the exact form of the casting is not of great importance, or when portions of prints are to be filled up by the moulder, more may be given with advantage. Those portions of the castings which have to be tooled must have additional metal put on in the pattern, to be afterwards taken off by the machine. Patterns must likewise be made somewhat larger than the finished casting in order to allow for the contraction of the material in cooling. Experience teaches the amount to be allowed for each description of work, but one-tenth of an inch to the foot is generally considered to be about the proper thing for cast-iron. With steel and brass a somewhat greater contraction takes place and so an allowance of about 3-16ths of an inch to the foot becomes necessary. The shaking necessary to loosen the pattern in the sand previous to its removal somewhat increases the size of the mould, and this is usually sufficient when dealing with small work to provide for the contraction of the material in cooling, so that patterns of small size are as a rule made as nearly as possible in accordance with the dimensions shown on the drawing.

The wood mostly employed in pattern-making is yellow pine. It is a soft, easily worked, straight-grained timber. Thoroughly seasoned wood should alone be employed in every portion of a pattern. If this fact be overlooked the pattern will shrink and twist and it may become perfectly useless. For small work and where a large number of castings are required to be made teak, mahogany, or bay-wood, and plane-tree are generally the woods used. Patterns of this nature are usually coated with a varnish made by dissolving shellac in spirits of wine or naphtha. Yellow pine patterns when made of properly seasoned wood ought to be painted. This prevents them from absorbing the moisture from the sand while in the mould and preserves them against atmospherical influences. Foun-

dry operations are likewise facilitated as when treated in this manner they part from the sand more readily. If an extraordinary large number of castings are required from the same pattern, soft white metal is employed for small castings, or a casting is taken from the wooden pattern if the form will admit of it, and afterwards used for subsequent castings. In this case the allowance for contraction on the wooden pattern must be double that given in this article.

TIMBER RESOURCES OF TURKEY IN EUROPE.

From "Journal of Forestry."

A FRENCH writer, M. Bricogné, has lately been at the pains to collect a large amount of information relative to the forest products of the Ottoman Empire, which is not without interest at the present moment.

Availing himself of the reports of M. Bzrozonski, late chief inspector of forests in the *vilaset* of the Danube, and other presumably reliable sources of information, M. Bricogné shows that the reported wealth of European Turkey in timber—like other reports circulated from time to time respecting that unhappy country—must be regarded with a more than ordinary share of reservation. The natural capabilities of the country in a forestal point of view are undeniable. Its diversity of surface, productive soil, and semi-peninsular position fit it to grow the finest timber in Europe.

Noble forests have been, and in some places still are; but, with few exceptions, the hand of the spoiler is everywhere seen. Ignorance and greed have destroyed Nature's gifts; and where valuable timber yet remains, it is, as a rule, because it is too inaccessible to be worth the trouble of reaching it. Differences exist between the several *vilazets* or provinces, but the remark applies with more or less truth to all.

Bosnia (including Herzegovina) was of yore one vast forest, and though sorely despoiled, still contains some of the finest oak and beechen woods in Turkey. Bosnian oak, mostly the peduncled and sessile-flowered kinds, with a sprinkling of *Q. Ægilops*, is not suited for shipbuilding, but splits well. There is a considerable export from the province, chiefly in oaken staves, deals, and firewood, the latter mostly beech and birch. Most of the stave-wood goes to Marseilles; the deals into Russia. During the six years 1868—1872, thirty millions of oaken staves, averaging 38 inches in length, 4¾ to 6 inches in breadth, and ¾ to 1½ inches in thickness, were thus exported. Large numbers of telegraph poles and railway sleepers are also cut, and over 18,000 tons of wood are annually consumed on the line of railway from Salonica as fuel, wood being found cheaper than imported coal. Bosnia is rich in surface minerals, and amongst other causes of sylvan mischief are mentioned what are known in France as "Catalan forges," a primitive mode of iron-smelting, which not only consumes much wood, but occasions frequent forest fires.

Of Albania little is known. It has fine forests of beech and fir, which are very inaccessible, and the export of timber is forbidden on political grounds.

Thessaly and Macedonia in bygone days supplied the dockyards of Salonica, and entire fleets were built of oak thence brought. The demand continues, but the supply has fallen off, and here, as in other parts of the world, the choicer descriptions of naval timber are no longer procurable. These woods still furnish a variety of forest products, from holm-oak charcoal to the tallest masts. Amongst the industrial establishments located there are mentioned a large manufactory of farm implements and numerous saw-mills in the mountains. Forests of conifers clothe the mountain sides, and about Mount Athos are noble forests of oak and chesnut, described a good many years since in that very entertaining work, Curzon's "Visits to

the Monasteries of the Levant" (1834), and which are still nearly untouched. They belong to the mountains, and some of them are said to date from the time of Constantine the Great (A.D. 313). Bulgaria, in the Middle Ages a vast forest, of which traces were still visible fifty years ago, now scarcely possesses wood enough to supply the inhabitants with fuel. As an illustration of the rapidity with which the work of destruction has gone on there of late years, the forest of Deli-Orman is mentioned. At the beginning of the present century it covered an area of 2,500 kilometers, and contained some of the finest oak in Europe; now it is reduced to between 30,000 and 40,000 *hectares*, full of clearings and mangled trunks. In Bulgaria, more than anywhere else, the effects of disafforesting are felt in the increased severity of the winters and the increasing frequency of droughts.

The *vilazet* of Adrianople—the ancient Thrace—appears never to have been much wooded; but it was the most populous and best cultivated part of the Byzantine empire. Then and afterwards, so long as agriculture flourished, the timber was respected; when it declined, the woods began to suffer. It is at present irregularly and sparingly wooded, but there are some fine woods of oaks, beeches, pines, and firs. The markets for the timber are along the upper course of the Maritza, in large towns like Adrianople, Tatar-Bazardjik, &c., and in Egypt and the Archipelago.

The *vilazet* of Stamboul at present contains but little timber, although it is said that at the beginning of the century the environs of Constantinople presented a fine growth of forest, which now no longer exists. Everywhere the destroyer has been at work. Even the forest of Belgrade, which encloses the reservoirs for the supply of the city, has been reduced within the last thirty years from 12,000 hectares to 7,500, one-third of which is clearings.

So far as authentic data are procurable, it appears that Turkey in Europe must still contain *at least* 1,425,000 *hectares* (three and a half million English acres) of forest and woodlands.

The varieties of timber are not numerous, but what there are are valuable. As a rule, the larger flora of European Turkey differs but little from that of Western Europe, and amongst the numerous shrubs which flourish luxuriantly on low warm sites, and which include the myrtle, citron, orange, olive, rose, &c., are very few but may be found in similar localities in the South of France.

Forest vegetation exhibits four zones, which now are very imperfectly defined, varying much in their vertical limits in different localities, and even in the same locality with different aspects.

1. The oak (chiefly the pedunculed and sessile-flowered varieties) and the chestnut rise, the former to an altitude of 3,200 feet, and the latter to about 2,600 feet.

2. The beeches are found, according to the locality, up to altitudes of 2,000 to 5,000 feet.

3. Resiniferous species—firs, larches, scarlet and Austrian pines, &c., are generally found between 2,600 and 6,200 feet above the sea level. In the Despotodagh—the ancient Rhodope—are still large forests of pines intermixed with firs, crowning the highest summits of Olympus, as probably they did when Euripides applied to it the epithet "many-treed." Here, 6,700 feet above the level of the Ægean Sea, is the highest woodland observed in Turkey in Europe.

4. The evergreen oak, the Judas tree, and a variety of noble arborescent shrubs, mingled with some woods of Aleppo pine, cover (where they have been spared) the low hills bordering the Ægean and part of the Sea of Marmora. On the Black Sea shores pedunculed and sessile-flowered oaks are found at all altitudes, coming down nearly to the water's edge. The oak, the tree *par excellence* of the Balkans, within its own vertical limits may be said to be the predominating forest growth everywhere in European Turkey.

Several distinct classes of property are recognized in Turkey in respect of standing timber.

First, there are the woods known as *korous*. These belong to private persons or village communities, both the land and the timber on it being private property.

Next come the State forests properly so called, which have been specially as-

signed to the use of some particular branch of the public service, as the Navy or the Ordnance. Then there are the *baltaliks*, woods of which a right of usufruct belongs, by ancient custom, to particular villages, the land remaining the property of the State. A sort of semi-proprietorship exists in the case of these *baltaliks*, as the users have a legal right to prevent strangers cutting wood in them, although they have themselves no right to sell or even to clear the ground.

Intermediate between public and private woods come those known as *vakoufs*, which have been left at some time or other for the use of religious foundations, and the management of which consequently rests with the *evkaff* or administration of mosque property and charitable trusts, which receives their revenue and defrays the cost of management.

Lastly, there are the public forests, which virtually belong to no one, but of which every one makes unrestricted use as though bent on their annihilation at the earliest possible moment.

According to both the letter and the spirit of the old Ottoman law public forests (*djebel mubah*) could only exist where the land was utterly valueless. The remoter parts of mountains, the face of cliffs, inaccessible peaks, and the like, alone were to be thus regarded as a sort of "no man's land," as the Arabic root of the word *djebel*, denoting a rugged mountain side, testifies. But in practice, particularly of late years, it has not been so. Wherever forest land, not being private property, has proved easy of access, or facilities have offered for its destruction, there both land and timber have been treated as *djebel mubah*, and worked accordingly. And it is a significant fact that wherever *djebel mubah* is recognized agriculture declines and disappears, leaving the population dependent for existence on the forests they are doing their best to destroy.

The Forest Department, which figures in the Turkish Budget of 1875–6 for a sum of £161,000 sterling, has proved wholly inadequate to meet this evil. The causes are too deeply seated. The disappearance of the flocks, the folding of which formerly provided for the amendment of the fields, the decline of tillage under the ever-increasing burden of taxation, the ignorance and obstinacy of the peasantry (in which respects the Christian populations stand conspicuous), not to speak of the squabbles between the *erkoff* and the officials of other departments, and the utter apathy and indifference of the Government, all have contributed to the results.

Private woods, as the *korous*, it should be said, are generally well preserved; and there appears reason to believe that with adequate forest management much valuable timber might yet be saved in various parts of the country, and, with the aid of improved communications, be turned to account.

However this may be, of the present state of the timber resources of Turkey in Europe there can be no doubt. The popular notions of forestry there prevailing may be summed up in the pithy words of a recent writer, who refers to the climatic changes the country has evidently undergone owing to disafforestment:*

"The destruction is truly pitiable, and the plains and low hills are for the most part denuded of trees. If wood is wanted for a fire, the nearest trunk is mangled with an ax to provide it; and if there is a ready sale for the wood, down come the trees wholesale, without a thought of the future. The idea of planting trees never enters into the head of Turk, Greek, or Bulgarian. It would be a present outlay for the benefit of posterity, which would appear to every one as the act of a lunatic."

Supersaturated solutions of many salts often spontaneously deposit crystals, which are less hydrated than the common salt. In many cases before the point of spontaneous deposit is reached, a crystal of the less hydrated form will start the deposit. In such cases a brisk friction against the walls of the vessel will often produce crystallization. D. Gernez has observed three modes of this mechanical action: (1) the simple production of the least hydrated crystals; (2) the production of the most hydrated crystals, in solutions where the other hydrate would form in contact with a crystal; (3) the production of either salt, under different degrees of friction.

* Baker's "Modern Turkey in 1877."

EMERY AND CORUNDUM WHEELS.

By ARTHUR H. BATEMAN, F. C. S.

From "Journal of the Society of Arts."

The two great divisions of the metal industry are the elimination of metals from their ores, and their working up into forms for use.

The first class involves highly scientific processes chiefly carried out by unskilled hands, the second necessitates individual skill on the part of the workers.

The chief means of working up metals are, casting, forging, and shaping, both of the former requiring more or less of the latter, and in each the removal of superfluous metal plays an important part. This is effected chiefly by files and chisels to some extent, and in some branches also by grindstones.

A file is a specially prepared tool, of which only a very small per-centage can be considered to be practically useful. A chisel is the same, and requires constant attention to its small cutting edge, the great bulk of its weight also being useless for its actual work. A grindstone, reduced to its elements, is composed of a large number of particles of natural material, mostly silica or its combinations, and the individual grains of which are irregular in hardness, shape, and size, mostly smooth and comparatively rounded. It will attack hard metals, which the file and chisel will not, but, owing to the difficulty of securing real homogeneity, it cannot with safety be run at a speed requisite to utilize its full cutting power.

For rapid working of hard materials whether metals or stone, &c., something harder and more lasting than these tools is required, and for many centuries natural substances have been used to assist.

It is probable many of the ancient gems now in existence were cut by the help of emery powder and to this day the Indian and Turkish lapidaries use a wheel compounded of shellac and this material rotated with a drill bow. This remarkable substance is often spoken of as steel filings, or as an oxide of iron, but is really a mixture of corundum and oxide of iron. Corundum itself is almost pure alumina with a little silica; and, in its purest form of all, slightly tinged with iron oxides, is sapphire and ruby; in a less pure state, and with traces of various foreign substances, it is of commercial rather than fancy value, and is found in unimportant quantities in various parts of the world. It is also known as adamantine spar. Comparatively recently large deposits of corundum were ascertained to exist in America, and it is a somewhat singular fact that this took place almost simultaneously with the discovery in 1847, by Dr. Lawrence Smith, an American geologist, of the now famous Turkish deposits of emery. The former, however, was allowed to lie dormant until 1865, while the latter, being brought to the notice of the Government, were almost immediately utilized. Further investigation showed these deposits to be of considerable magnitude; the chief are near Smyrna and the ruins of Ephesus, also in several islands of the Greek Archipelago, notably Naxos, from a promontory in which island—Cape Emeri—it takes its name. Deposits of little or no commercial importance are also to be found in Jersey, Spain, Poland, Saxony, Sweden, Persia, and the Andes of South America. Quite recently, it is stated, important discoveries of emery in a granular form have been made at the Adirondacks on the North American Continent.

Although called mines, the emery workings are really on the surface only, or very little below the surface. The dark red color of the ground affords a pretty sure indication of its presence, but steel rods are stuck into the earth and a practised eye soon detects the presence of emery rock by the marking on their points. The mineral occurs chiefly in large masses, sometimes susceptible of rough breaking, at others resisting blows. In such case, a fire is lighted round the refractory lumps, and on cooling, after some hours of heat they will often be found more amenable to treatment. Blasting is seldom practicable, from the difficulty of drilling

holes. As transport to the sea is solely attainable on the backs of mules and camels, a weight of about 100 pounds is considered the practical limit for individual lumps. The Turkish and Greek Governments sell the monopoly of raising emery rock, and for many years nearly the whole has been controlled by English capitalists, in fact, until recently a company known as the Levant Company have had the practical control of the market. During the last few years there has been more independent working, and the supplies have been large, but at the same time, a greatly increased quantity of inferior rock has come to England. It is chiefly sent over as ballast; freight thus is an insignificant item.

The specific gravity of emery ranges from 3.75 to 4.28, and may be taken to average 4.0; the color varies from dark grey to black, and is no indication of value. Owing, however, to general misappreciation of this fact some English firms color their crushed emery to a uniform tint, and uncolored emery is often unsalable, and put down as bad or impure by buyers used to a particular shade.

Nothing is done in the producing beyond the rough sorting and breaking into lumps under the above limit of weight. On arrival in this country the emery crushers submit it to treatment, to render it available in manufacturing processes. There are but few firms in this trade—until within a few years since only four or five, but at present more are engaged in it. As a rule, emery crushing works are not shown in operation. Several processes are employed, each being held to possess its own special advantages. First the rock is smashed into pieces about the size of walnuts, by passing again and again through Blake's or other crushing machines; it is then either stamped with stampers, passed between chilled rolls, or through grinding mills, the latter being circular cast-iron plates with upright lands six or eight inches high. These wear away by degrees as may readily be believed, but last from four to six weeks. The jaws of the crushers last from two to three weeks, stamps last longer and work slower; of the life of chilled rolls I have no information. Microscopic examination of crushed emery shows, not only the distinct presence of the two substances, corundum and oxide of iron, with a certain per-centage of quartz which is often mixed with the emery rock, and a trace of iron from the machines, but also in many instances iron slag and other similar substances used as adulterants. It is by no means certain that some such substances may not be a positive improvement in some respects, as causing a freer cut; but in this case it is certainly desirable that any such admixture be made by the user and not by the crusher. All makers of solid emery wheels guarantee that they use pure emery, but, as only one firm crushes its own rock, the microscope should always be used to see that what is bought as pure emery really deserves that name. The microscope also shows that there is little, if anything, to choose between the grains produced by rolling, crushing, stamping, or milling, as far as regards sharpness of angle. The great points seem to be attention to quality of rock, careful removal of bad pieces containing foreign matter, and accurate sifting.

By the kindness of Messrs. Acton & Borman, who have large emery crushing mills, I am enabled to show a very good selection of emery rock, good, indifferent and bad.

After the emery has passed through the machines it is sifted through a series of sieves ranging from 6 to 100 linear meshes to the inch, and all pieces larger than the former size are returned to the machines for further crushing. The process is an eminently dusty and disagreeable one, and from the beams, roof, and upper parts of the crushing shops is collected what is known as flour emery which has deposited from the atmosphere. Finenesses of 120 and even 140 are thus obtained. Still finer grades are, however, required for polishing plate glass, opticians' work, &c., and for this the very beautiful process of elutriation, or washing over is employed. A dozen or more metal cylinders, three or four feet high, and ranging from three inches to 36 or 40 inches in diameter, are connected near their upper edges by pipes; the whole series is filled to the brim with water, emery and water well mixed are introduced into the smallest vessel; the

water of course flows out at the opposite pipe to the next, and so on through the whole series. The coarsest powder falls during its three inch journey across the first cylinder, the next coarsest through its four inch, then its six inch, and so on until at last practically pure water flows from the exit tube of the last 40 inch vessel. After a time the process is stopped, the material allowed to subside, the superincumbent water decanted off and the deposited emery removed and dried. This process is carried out by the users, not by the crushers.

The chief use to which powdered emery has been put is, in its raw state, in metal workshops, also for glueing on to sticks of the shape of files; for use with lead laps or polishing wheels, and glued to paper and cloth, in which form it is generally used by mechanics, wrapped round a stick or flat piece of wood. Paper seems better for this purpose than cloth, though the latter is preferable where it is used without such support. Envelopes of emery paper with shaped sticks have also been patented, but have never come into general use. Emery has also long been extensively used for buffing and polishing, by covering a wooden disc with leather, glueing fine emery on to the surface, and rotating it when dry at a high speed. The yielding nature of the latter causes this to be absolutely unsurpassed as a polishing medium for hard metals or other substances.

In 1842, Henry Barclay patented a process for a solid emery wheel, using an equal part of Stourbridge clay and emery, pressing the wet mixture into moulds, and subjecting it to a bright red heat. This is said to have given a really efficient wheel, but it does not appear to have been practically worked, as only small discs, say eight or nine inches diameter, could be made, owing to the difficulty of avoiding cracks and distortion in the process of firing. It is satisfactory to know that the actual father of the modern emery wheel was an Englishman, although the development of the idea has certainly taken place on the other side of the Atlantic; and we are now appearing to be copying our American cousins in our tardy adoption of a *bona fide* English invention. About ten years later, I believe, efforts were made to introduce and extend the use of solid emery wheels by Mr. (now Dr.) Anderson, then of Woolwich Arsenal, but it has only been during the last five or six years that anything approaching to general attention has been paid to the subject.

Five years ago, there were many makers of solid emery wheels in America, but only about four in England; at the present moment there are double this number, and one of the leading American makers is personally represented in this country. Notwithstanding the depressed condition of the metal trade, the sales of most of these makes have probably something like doubled annually of late, showing that the subject is one assuming real commercial as well as scientific importance, and worthy of the attention of the members of this Society.

An important peculiarity of emery or corundum is its extreme hardness. The diamond is the hardest substance in nature: absolutely pure corundum, in the form of sapphire, and ruby comes next; the commercial variety is scarcely inferior, and closely approaching is emery; but a still more important feature of the latter substance is its tendency to break with a rough surface, or what is known as concoidal fracture. However finely the rock may be crushed, this roughness still exists, and even flour emery, examined under a moderately high power, is found to sustain this peculiarity, and to present a series of sharp angles and points. As an individual grain wears smoother by friction, it still, to a great extent, carries out this disposition, so that a disc or wheel made of grains of emery, if properly cemented together with a binding material that will not melt and form a skin on the cutting surface (as is sometimes the case), presents absolutely a constant succession of fresh cutting surfaces.

The question has been asked, whether a disc of solid emery rock would not be better than crushed grains cemented together again. The answer is obvious, that the vast amount of rough surface present in the built-up wheel would be absent in the solid mass, quite apart from the extreme difficulty of manufacture.

The peculiar property of conchoidal fracture above referred to, as possessed by emery, is not shared in anything like

an equal degree by corundum, and although in crushing this latter mineral many sharp points are obtained, there are also considerable plain and curved surfaces, never seen in the somewhat less hard emery. The result is as might be anticipated—the process of manufacture being the same, a disc of corundum will, under similar conditions of running, do as much or perhaps more work than a similar disc of emery, but it will heat the metal much more, because, while emery with its sharp points cuts its way, corundum with its harder but smoother faces tears its way into the work. For certain purposes, where it is possible to run in a constant stream of water, corundum wheels appear superior to emery; but for the general run of engineers' work, which is certainly on the whole done best dry, for tool grinding, and indeed most other purposes, our English experience is so far vastly in favor of emery over corundum wheels. A common form of corundum is that known as "ruby," this is found in small grains averaging about 24 grade. It is waterworn and rounded, and breaks with comparatively smooth faces. This material, crushed, however, makes very good fine wheels.

The natural corundum of North America which is much rougher in grain has been specially worked up by Messrs. Morton, Poole, & Co.. of Wilmington Delaware, with the special object of trueing chilled rolls. I am not aware of the process used, but am informed that extremely good results have been obtained. This same operation is, however, conducted in Belgium, Germany, and elsewhere, with emery wheels, with entire success.

The microscopic projection on the screen of actual grains of emery and corundum clearly shows the peculiarities of the respective substances; and to emphasize the distinctive characteristics of numerous small points *versus* larger points and wide planes, I add projections of sands, crushed grindstone, flint, and glass. You will observe at once that the sharp points of the latter substance must give good work until broken off, when the cutting power will vanish. You will also note the smooth and round appearance of the grains constituting the ordinary grindstone.

These projections indicate the probable relative cutting power of the various grains available for the manufacture of grinding wheels. It now remains to consider the best means of agglomerating these grains into a solid mass and utilizing the same.

It is manifest that, by the adoption of the circular form, steam power may be used instead of manual labor, and if a cement of sufficient strength be employed to withstand the centrifugal force (which increases as the square of the velocity), we have the remarkable result of, on the one hand, a steel file moving at the rate of about 60 feet per minute, driven by a man whose arms grow tired, and the tool itself useless when under 5 per cent. of its weight is used up, and on the other, a circular file much harder than steel, whose cutting face never grows dull, driven by a steam engine, which never gets tired, at a speed of 5,000 feet per minute, and which can be used up to the extent of about 90 per cent. of its original weight. Small wonder, therefore, is it, that rapidity, economy, and precision are obtained by this new tool, and that it has shown rapid growth since it first obtained a footing in English workshops.

Circular steel files (of which a specimen is on the table) have been tried more than once, run on a lathe or other rotating spindle; but their high cost, and the difficulty of preserving a flat face during the hardening process, and the small percentage of useful material, combined to prevent them coming into general use.

It may be asked if one half of what is claimed for the solid emery wheel be true, how is it that, instead of a gradual introduction, it does not instantly take its place in every workshop in the kingdom?

The answer is fourfold. 1st, the English workingman (and to a certain extent the master also) is intensely conservative—why should he now use a tool he has done without all his life? 2nd. It is said we cannot be perpetually adopting American "notions"—forgetting this is really an English notion adopted by the Americans, because they have found it to be a real economy, which enables them to positively compete with us in our own markets, in the face of the heavy charge for 3,000 miles of

carriage. 3d. It has already been tried and found a failure—probably put to unsuitable work, something that could not be done any other way, and an expectation formed that the new tool could be used in a moment without practice, condemnation following, because immediate success was not obtained. 4th. A dread, or fancied dread, of the necessary speed—quite oblivious of the fact that our trains run faster, our circular saws run faster, our wood working machines run faster, and that with the proper and ordinary precautions requisite in all high speed machinery, there is no more danger than with many tools in everyday use already.

The novelty of emery wheels has caused the few accidents that have happened to be noised abroad, while those occurring with grindstones excite little attention. After considerable research, I am unable to obtain actual figures on this subject; but there is little doubt in the minds of those qualified to judge that the per-centage (not the actual number) of emery wheel and grindstone accidents, is much in the same ratio as those of railway trains as compared with stage coaches.

It may again be asked, have any firms of repute, after introducing emery wheels, discontinued their use? In some few cases this has been the case, the reason being given that the opposition of the workmen did more harm than the use of the wheels did good; but coupled with the avowed intention to try again later on. On the other hand, the firms who have extended their use of this labor-saving invention, after their first trial, are large in number and an ever increasing quantity. In many shops grindstones have vanished; in others the file bills have been cut down to one-half and one-third; in others, again, work heretofore impossible has been successfully accomplished, and materials hitherto unavailable have become admissible. A file can cut nothing harder than itself, and hard steel and chilled cast iron defy it. These materials are readily amenable to the solid emery wheels, and a new art has sprung up with their introduction—that of shaping dead hard metal either flat or cylindrical, instead of turning and subsequently hardening, the latter process not infrequently resulting in the destruction of accuracy by twisting and warping. Specimens of such work are on the table.

To the manufacture of a good solid emery wheel three essentials combine—good emery, good cementing materials, and extreme care in their combination. Probably the earliest commercially successful solid English emery wheel was that introduced 16 years ago, under the patents of Cole, Jacques, and Fanshawe, in which the cementing material is that curious compound known as oxydized oil largely used in the well-known linoleum. The cement and emery are intimately admixed, pressed into accurate metal moulds, and subjected to a high temperature under the action of superheated steam. The resulting wheel is remarkably strong and homogeneous, is susceptable of manufacture in very thin discs, being to a certain extent flexible, and although giving off some slight smell in use, is widely accepted as a very valuable wheel. Another form is manufactured with shellac as its binding material, the ordinary smell of this substance being almost overcome by a peculiar mode of manufacture not made public. This process can be applied also to covering light iron pulleys, rims, and plates of metal, and is said to give good results.

A recent introduction to this country is the manufacture of what is known as the Union wheel in America, but is here called the Magnesian, from the fact of the cementing substances being oxychlorine of magnesium. A positive stone is the result, for which enormous inherent strength is claimed, while a low rate of speed is, nevertheless, recommended as the best for cutting. Yet another process is that of Mr. F. Ransome, in which silicate of soda (dissolved flint) being mixed with the emery grains together with a small proportion of free lime and natural soluble silica, double chemical decomposition is set up, resulting in the almost entire change of the three cementing substances into the one insoluble silicate of lime, which binds the emery in enormously strong bonds, the action being facilitated and hastened by the application of gentle heat, not baking as is sometimes erroneously stated. A remarkably strong and

free cutting wheel is the result. Being hard and unyielding, thin discs require considerable care in use, but the inherent strength of the material is enormous, and when sand is used as the base instead of emery a most successful building stone is produced.

Two or three other processes are also used in England, but are not made public. Sample of the wheels referred to are on the table with portions of the majority showing the internal structure of the finished wheels.

On the European continent, besides imported wheels, there are several local makes of varying degrees of merit, but mostly cheap (or rather low priced), and with greatly less cutting power than English and American wheels.

In America, the natural home, at present, of the solid emery wheel, the processes are numerous and the sales very large. The Tanite, now represented in England, has long enjoyed the reputation of being the standard wheel; it is the highest priced; the cementing material is believed to be a solution of leather. The Union wheel (called Magnesian in England) took the Philadelphia Exhibition medal in 1876, and now claims to be the leading American wheel; it is sold in England under the auspices of a highly respectable London firm. Others may also be named; the Northampton, enjoying a good reputation; the Vulcanite, calling itself the genuine and original; the Climax, claiming to be made of American emery, recently discovered in the Adirondacks, and to dispose of a cubic inch of cast iron in 49 seconds; the Vitrified, a porous wheel with a central water supply, the Cosmopolitan, and many more. Each of these wheels —or rather their makers—claim to be positively the best, some advocating high, others low speed, and generally indulging in those little amenities at the expense of their rivals, fortunately more common across the water than with us.

In conclusion, a few practical remarks may be offered. A common delusion prevails that an emery wheel is a tool requiring neither skill nor practice, and it is left to anyone who chooses to work it. The result of this same system, as applied to grindstones, has caused that article to assume the simply disgraceful appearance it often exhibits—untrue, worn into grooves and hollows, no one responsible for keeping it right, and the result utterly wrong. This system pursued with emery wheels is simply fatal to their chance of success.

Mount an emery wheel on a suitable machine on a ridge foundation (do not put a heavy wheel on a light spindle), run it at proper speed, checking the calculation with a speed counter, keep it always absolutely true with the diamond (a tool not half enough used), press the work lightly on the wheel—"crowding the work," as it is called, heating more and doing less than gentle pressure; appoint a careful man to use it and make him responsible for its condition, allow him a reasonable time to learn and understand a new tool, and one possessing very great and very unusual power, and the result cannot fail to be satisfaction of the highest degree. But set an ignorant or prejudiced mechanic to a badly appointed machine, with untrue wheels, and expect him to turn out as good work in an hour as he does by other means after years of training, and the result, of course, will be disappointment and condemnation of the unfortunate emery wheel.

This may be considered an overdrawn picture; any manufacturer or traveler will tell you it takes place every day. Again, do not commence your emery work by attempting to do something you cannot do with ordinary tools; get accustomed to the new system, and then apply it to the difficult jobs.

Emery grinding can no more be learnt in a day than the proper management of a lathe or planing machine. Further, give an emery wheel a fair chance by mounting it properly (at present engineers will pay hundreds for a good lathe or planing machine, yet grudge twenty pounds for a proper frame for an emery wheel), in short put emery wheels to work they are suited for, be content to spend some time in learning to use them and the result cannot fail to be satisfactory in England as in America.

For ordinary fettling and general rough work, the simplest, cheapest, and quickest way is to hold the work in the hand against the wheel occasionally dipping in water to keep it cool, a good wheel not being prejudicially affected thereby. For tool sharpening and grind-

ing, a small stream of water under some pressure thrown on to the tool is advantageous, but if much metal has to be taken off in consequence of a deep chip, broken point &c., it is generally the quickest plan to ignore the temper, grind rapidly, and then re-temper. For really accurate work, of course mechanical feed is essential; flat surfaces being fixed on the traveling table and traversed under a revolving wheel: cylindrical articles are rotated in a lathe, an emery wheel fixed in a holder in the slide rest, being revolved by an independent strap, and fed against the work to be operated upon. Long bearings are desirable for the high speeds required for emery wheels, but there is no absolute rule as to material; brass bearings work well as do white metal, and considerable success has been achieved by the new bearing called metaline, a method of treating brasses, obviating the use of oil or any other lubricant. Absolute rigidity, firm screwing home of all nuts, &c., are manifest necessities when high speed is employed.

A solid emery wheel does not profess to polish, it cuts; and to polish there is nothing to surpass the old leather buff previously described, the elasticity of the leather rendering a very fine polish obtainable, with little or no signs of scratches; but the solid wheel prepares work admirably for the buff, and enables it to be used only for its legitimate purpose, thus causing it to last greatly longer than if used to rough down as well as polish.

Emery wheels may be improved in the future, but as at present prepared they do extraordinary work; the chief field for improvement is in the mechanical appliances to use them in. If an elaborate and expensive machine is required to actuate and utilize a simple point, it is equally required for this revolving file. Some such exist, and I now proceed to project on the screen representations of some of the more interesting English and American machines.

While the essence of emery grinding is high speed, that alone is not sufficient. I exhibit a plate with half-minute cuts made by $12+\frac{1}{2}$ emery wheel and same size grindstone, each running at the same speed (the latter of course carefully protected by large side plates), showing in a remarkable manner the difference in cutting power. The respective wheels that did this work are on the table. The first cut shows little difference; but it will be observed while the emery retains its cutting powers, the grindstone rapidly loses it, until, in the fourth and fifth cut, there is an enormous difference.

I am sure I am justified in saying that the several firms now engaged in this manufacture in England will willingly give opportunity, at their respective works, to any persons here present, or their friends, to test for themselves the statements and claims put forward on this occasion; and finally, I trust that the ventilation and discussion of this subject will lead to the more rapid introduction of one of the most wonderful labor-saving inventions since the practical application of steam, with the desire that our own proud position in the foremost rank of producers of machinery and general metal work, to the benefit of our manufacturing industries and the increased reputation and profit of both employers and employed throughout the British Isles.

THE first railway opened in Japan was from Yokohama to Tokio, eighteen miles long, of narrow gauge, and with carriages of light construction, similar to tramway cars. The journey from Yokohama to Tokio occupies about an hour. A prolongation from Tokio to Tagasaki is now being surveyed. The Kobe and Osaka line, twenty-two miles long, was opened in 1873, and that from Osaka to Saikio or Kioto in February, 1877. These two are broader gauge, with substantial works, well-built stations, and the usual type of rolling stock. The three have been built and superintended by English talent, and the material and rolling stock came from England. The line from Kobe to Saikio is to be completed by a line to Isuruga. The idea of connecting Saikio with Tokio is abandoned for the present, the Treasury being too heavily loaded, the debt contracted to the date of the report having been 152,000,000 yens, or 836,000,000f. With regard to tramways, a Belgian company is endeavoring to obtain the concession for one at Tokio.

NOTES ON JAPANESE ARCHITECTURE.*

By Mr. JOSIAH CONDER.

From "The Architect."

In venturing to accompany several sketches made by me in Japan with a short Paper upon Japanese architecture, I feel in no small measure how imperfect is the knowledge that I have as yet been able to accumulate on the subject. As, however, it is one upon which not very much has been written, especially from a professional point of view, I beg permission to lay before you my scanty notes, hoping for a future opportunity of enlarging upon them after longer and closer observation and more extended travel in the country. The most noteworthy buildings being those devoted to religious purposes, consisting of the ritual of a most complex mixture of faiths, combined with the deification of deceased historical heroes, it is a matter of no small difficulty and research to form a clear analysis of the meaning of their arrangements and peculiarities. There is much to be done at some future time in comparing the forms of Buddhist architecture here with that of India and China. The introduction of Buddhism into Japan from Corea dates 552 A.D., but it remains to be seen how far the religious architecture is a pure imitation, and how far it is a modification of that of China; how far it has been simply copied, and how far grafted on to an original style, or afterwards modified by the inventions of native artists or by religious reformers.

All Japanese architecture, until the employment of foreigners within the last few years, has been, with very few exceptions, entirely of wooden construction. In certain parts of the country, where stone lies to hand in boulders or is otherwise naturally exposed, there are a few instances of its use in the construction of the walls of small houses and simple temples. There is a small temple near Nikko, about fourteen feet square, of which the walls are built of oblong blocks of stone placed upon their narrow ends, forming the whole thickness of the wall, without bond, and having all the external joints covered with a large plaster roll to keep out wet. The roof is also formed of large slabs of stone hollowed out on the surface and cemented at the joints in imitation of tiles. In addition to this there are to be seen several stone bridges—large stone walls surrounding the principal cities, solid stone monuments to the dead, imposing flights of stone steps with stone railings leading up to the temples, lamps of stone and bronze adorning the temple precincts, bronze statues of gigantic size; and stone is invariably found employed in the pavement of courts, and as a sub-structure to wooden buildings in order to form a stable and dry foundation. On account of the constant fires which occur in the large cities, particularly during the winter, there are not many of the ordinary street dwellings which have not been repaired or rebuilt within quite recent times. The temples, protected by their isolation and in many cases by thick groves, also many important dwellings set apart by themselves can boast considerable antiquity, but the ordinary domestic and street architecture is of comparatively modern erection. Some of these larger dwellings of the nobles have fallen a prey to treachery and wanton destruction, others have been burnt to the ground through the introduction of English heating appliances into wooden walls without precautions and protection. The Tokio Foreign Office, one of the finest old Japanese buildings in the capital, which was entirely destroyed this year by fire, is said to have been set on fire through a stove pipe running through a wooden wall without any protection whatever. It appears, nevertheless, from such representations as can be found in books, that the arrangements and general appearance of the ordinary houses have not altered since very early times. They are fragile wooden structures, never more than two stories in height. The walls are constructed of a vertical and horizontal framework of posts and beams morticed together, filled in with bamboo

* A Paper read at the Royal Institute of British Architects on March 4.

laths, laid crossing, bound together, and coated with mud in several layers, being finally plastered over. Sometimes the beams and posts show, being flush with or projecting beyond the plastered surface, and sometimes the whole is plastered over framework and all. This latter method is employed in larger buildings, and in the "Kuras" or Godouns. A Kura is often many months in building, the mud, which is taken from the bed of some river, being spread over the framework in a great number of layers, each layer being allowed a long time to harden. The projecting timbers at the eaves are also thickly coated with the same clayey mud, and to the small window openings are hinged shutters coated to a very great thickness with the same material. The whole surface of the building is then plastered over, and finally covered with a coating of lacquer. These Kuras often remain standing after street fires, but they are by no means thoroughly fireproof, for the mud often cracks and falls off with great heat, and even under ordinary circumstances they require constant renovation and repair.

In the ordinary houses one external wall or more, and most of the internal walls, are not filled in with plaster, but are open between the uprights, being filled in merely with light wooden screens sliding past one another in grooves formed in the heads and sills of the framework, so that the whole partition can be thrown open at any part. Where light is required these screens are formed of thin wooden framework, divided into rectangles of some simple design, and filled in with tough translucent paper, or in some cases in interiors they are covered with paper, decorated with patterns or paintings. Each room opens into the neighboring rooms, and passages are seldom to be found, except in the largest of houses. Sometimes, however, the greater portion of a room will be raised about twelve inches above the level of the entrance, leaving an L-shaped space or passage on two sides. The raised portion is covered with mats, and used by the indwellers as the room proper. In small rooms the whole floor is on one level, and covered with mats. These mats are always manufactured of one dimension (namely, two feet eleven inches by five feet ten inches, being twice as long as their width), and a room is invariably built, measured, and described, not according to its actual dimensions, but by its number of mats. They are made of rushes neatly woven upon a light wooden frame, are about an inch and a half thick, soft, slightly yielding and warm. The houses of the highest and the lowest, as well as all temples, have their floors covered with these mats, a little differing in quality. There is generally in one wall of a room a small recess formed in the framework, in which are placed one or two rows of shelves moulded, polished, and lacquered. These shelves are generally arranged in some quaint unsymmetrical manner, and both form an ornament to the rooms themselves, and serve for the display of vases or small ornaments. Even the lowest classes of the Japanese show great taste in judiciously disposing small treasures of good shape aud color to the adornment of their dwellings. They convert the smallest strip of land into a miniature garden, which they plant with well-trained shrubs and flowers.

The simple habits of the Japanese, both as regards resting and feeding, renders but little furniture necessary for the complete comfort of the householder. Small low tables, more like what we call trays, are used for serving up food upon —one being set before each guest. A metal-lined box, or sometimes an ornamental bronze receptacle, is used for the small charcoal fire, from which warmth is obtained in cold weather. A room is invariably provided with one or more folding screens which, as the inmates sit or recline on the mats, do not require to be of any great height in order to secure privacy, and keep off draughts in cold weather. Small chests of drawers are to be found in private rooms for clothes, &c., and these, as well as the hibachis, tables and screens are mostly of some elegant shape and pleasing design. If a house be of two stories, the upper story is reached by wooden steps, leading up from room to room, being composed of two strings with treads and no risers, somewhat inconvenient in their slope and generally without handrails. The ceilings of the rooms are wooden, consisting of the underside of the floor boards of the room above, crossed by the small

joists supporting them, and sometimes smaller ribs between, dividing the surface into squares; the whole is polished or lacquered. Probably, in early times, houses of this class were covered with thatched roofs, projecting considerably at the eaves, or were covered with boarding and wood shingle.

In country parts there are now many roofs covered in such ways, but most of the houses in the cities have heavy tile roofs of great projection, with large ridge and hip tiles and terra cotta ornaments at the extremities. The roofs are often slightly concave on their surface, resembling those found on a larger scale in the temples, from which they are undoubtedly copied.

The Shintoo Temples, which are built in imitation of the earlier temples of that region, prior to the introduction of Buddhism, have roofs of two plane sloping surfaces, very salient at the ends and at the eaves; and it seems from this that the heavy curved and hipped roof, which now abounds so in Japan, was an introduction from Corea or China contemporary with the religion of Buddha. The tiles are always of a grayish black color, and the joints are covered with a thick roll of white cement. One great peculiarity is the size of the ridge and hip ornaments, which are constructed of several courses of tiles and cement, forming quite a little wall along the ridge and hips, terminated by large terra cotta ornaments at the extremities. These ornaments are most of them very artistic in shape.

In houses of two stories the upper story is sometimes set back a little, the projecting portion below being covered by a small lean-to-roof. There is often below this another flat roof projecting some three feet from the lower wall to keep off sun and to protect the frail wooden entrances from wet. The roof is generally in part suspended from the roof above, and partly supported at wide intervals by light bamboo posts. Small gutters of bamboo are generally fixed to these lower eaves, with pipes of bamboo to carry off the water. In the hot season "sudaris" (a kind of cane blind which admits air and permits outlook, and at the same time gives shadow from the sun) are hung from the eaves to the ground. The above description applies both to the dwellings of the lower and the middle classes, the latter being somewhat larger, more cleanly, and better furnished.

The tea houses or hotels are on a much larger scale, and vary in their arrangements. They are very often planned on three sides of a little entrance court laid out as a garden—a verandah with a floor some twelve inches from the ground running round these sides and serving as a passage from one room to another. The upper story also has generally a verandah covered with a salient roof, under the eaves of which paper lanterns are hung at night. In large hotels (called Yadoyas) there is generally a small interior court, in one corner of which cooking is conducted in the open air, the rest being laid out in some ornamental manner, with ponds, streams, shrubs, and stone lanterns. Round this is an interior verandah, and often miniature wooden bridges enabling one to cross the court without dirtying the feet.

The dwellings of the higher classes, which are called "Yashiki," or "Miya," are considerably larger and more architectural. Their arrangement is very simple, being a group of somewhat low rooms, opening one into the other, having a lobby or hall at the entrance, and sometimes one passage from front to back. They are not more than two stories in height, and are covered with a heavy tile roof of wide span with terra cotta ridge and hip ornaments, prominent eaves often supported by a rich cornice of beams and brackets, and having elaborate carving displayed in the gable ends. Over the entrance to the house there is a wide portico, supported upon strong posts which are often moulded on the edges. The lintels, beams and projecting rafters are also moulded on the edge, and carved with some flowing line of ornament, deeply incised upon the flat surface. Such ornament is very effective, being delicately and sharply cut, and can be seen from a great distance. The portico roof is either a continuation of the curved line of the large roof or consists of a smaller roof intersecting this. In the latter case a favorite form is that of a double ogee, convex at the ridge and concave at the eaves, forming a gable or

semi-gable at the front. By this is meant, that on the front the curve of the roof is continued half-way, and is then, as it were, cut off, showing the sides of the end rafters projecting, decorated with bronze clasps and adorned with carved and pierced wooden pendants. In the large roofs the semi-gable is also a favorite form for the ends; in this case the upper portion is of the gable form and the lower portion a sloping hipped-roof. What I have called bronze clasps or belts correspond to what, if placed at the end of a beam, would be called shoes, being gilt and engraved plates of metal placed in the center of exposed beams and lintels, serving for no purpose but ornament. They are much used in Japanese architecture. The windows are generally greater in length than in height, being low oblong openings filled in on the outside with thick wooden bars, arranged sometimes vertically and sometimes horizontally, the whole being open to the air. On the inside of these windows there are always sliding shutters or paper windows, to keep out wet or cold in bad weather.

The Japanese seem greatly to seek privacy for their houses; even when they are placed in country districts they are mostly fenced in. They sometimes have an open loggia to the upper floor as in the hotels, from which they can enjoy the surrounding view; but the approach to the house is invariably shut in, and the lower story hidden by high railings of bamboo. In houses of one story this fence often reaches as high as the eaves of the roof. The Yashikis are shut in in a similar manner, perhaps with a view to protection from treachery as well as the love of privacy. Not only are the whole grounds surrounded by a high wall on three sides, with a long range of buildings and strong gateway on the entrance side, but there is often a high wall or fence close up to the front of the house, through which the open portico projects. Between this and the outer gateway, with its range of buildings, there is a paved court, on the two sides of which servants' quarters, stables, and other outbuildings are erected. From the street the outer gate and its surrounding buildings present in many cases a very pleasing façade. The long horizontal lines of ridge and eaves, as well as the horizontal effect obtained by the lower story being constructed differently from the upper, is relieved by the vertical window bars and projecting bay windows on each side of the large recessed wooden gateway. The gateway itself is of very solid and strong appearance; thick posts, carrying heavy wooden lintels, which support the upper story over the gateway, from the framework of the heavy doors. Both the posts, lintels, and doors are lavishly shoed, belted, and adorned with plates of engraved and gilt bronze. There is in some of these low buildings, marking the approach to a Daimoi's dwelling, a simple grandeur of line of proportion and balance of parts, reminding one as much of the repose and beauty of Greek architecture as the Japanese decorative ornament in many of its forms and in the beauty of its execution reminds one of Grecian art. The walls are generally placed upon a base formed of two or three courses of stone. The lower story, instead of being plastered upon the outside, is sometimes covered with large tiles placed square or diagonally. They do not overlap, but are fixed to the laths, side by side, the joints being protected by a large roll of cement. The tiles being dark grey and the cement white, this treatment presents a somewhat curious, bold, checquered appearance. Placed symmetrically on either side of the gate are often two square projections, about nine-feet by six feet, of one story, with an ornamental curved roof and carved gable. They correspond to our bay windows, and command a side view of the gate for porters or a guard who occupies these rooms. These projections have also a stone base, and are framed about four feet from the ground, with window bars and transoms placed very close together. They are protected when necessary by sliding shutters from within. Such windows also sometimes occur at the ends or the center of the range of buildings on either side of the gateway. The other windows are either oblong openings, with thick wooden bars, or they are small projecting windows, framed out some few feet above the ground, and supported on carved or moulded wooden brackets at each end. This framework is sometimes perfectly open at the bot-

tom, the whole front and sides being filled with close bars, and the top covered by a small curved lean-to roof. The inside is protected by sliding shutters flush with the inside of the wall of the room. In some Yashikis in Yedo these projecting window openings are continuous, running nearly the whole length of the building, with brackets at intervals. The whole of the exposed woodwork (gate-posts, lintels and windows) is often lacquered in black or a dull red color.

The smaller and inferior Yashikis are often of one story only, and instead of being plastered or tiled, are frequently boarded with planks nailed on to the wooden framework slightly overlapping at the lower edge to carry off wet. The whole is stained a dull black color. The outer walls, referred to as being placed round dwellings of this class, are either fences made of strong wooden posts and beams covered with planking, and protected with a little tile roof supported upon brackets at the top; or they are of considerable thickness constructed in alternate layers of tiles and cement, the cement being as thick in its layers as the tiles. The top is protected from wet and decay by a little projecting tile roof, with ridge tiles and ornaments similar to the roofs of small buildings. There are no instances of the walls of dwellings themselves being constructed in this way with tiles and cement. At the back of the dwelling within the surrounding walls are large grounds, generally laid out very prettily as a landscape garden. These Japanese gardens abound in grassy mounds and terraces, planted with an endless variety of trees and shrubs fantastically trained, with groups of large stone slabs and boulders, running streams, small lakes, fancy bridges and stone lanterns.

The military architecture of Japan seems not to have been much more substantial than the rest, though many cities contain large moats and the stone walls within which the castle buildings stood. The central portion of the city of Tokio is surrounded several times spirally by a deeply-cut moat with large grassy slopes. Towards the center, this spiral forms a complete enclosure, and on the inside of this inner moat is a thick stone wall constructed in large polygonal blocks, which originally carried wooden defensive constructions surrounding the castle within. The larger number of these wooden constructions were pulled down some years ago, but those few that remain form, with the solid walls, deep moats and strong gateways, an extremely picturesque feature of the city. Comparing these remains with a rough plan of a castle, taken from a Japanese book, it appears that there were in the center enclosure of these fortresses three principal buildings of a tower-like form. The most important and the highest of the three, called Homaru, was immediately under the chief in command, and for the use of him and his retainers. The second, which was somewhat lower, called Ninomaru, was devoted to the use of the second in command; and the third, lower still, to the third in command. This last was called "Sannonaru." These buildings were of two, three, or four stories, placed upon a solid battering stone basement similar in construction to the surrounding walls. Each story is set a little back within the lower, the projecting portion below being covered with a very salient roof, adorned in some instances by little excrescent roofs presenting richly-carved gables. The top roof, which is generally hipped, is slightly concave and has a very bold projection. The towers are often oblong in plan, and then the ridge of the roofs ends in a small gable terminating in a hipped roof. These crowning roofs also carry little dormer gables, apparently neither used for light nor ventilation, but as ornament; they are generally little roofs of a curved form. In addition to these dormers the ridge and hip tiles are richly adorned with finials at the extremities, the ridge often terminating in a large representation of a dragon or fish with the tail curled upwards, executed in copper. The walls are thicker than those of ordinary houses, but are constructed of wood filled in with mud and plastered over, showing only the wooden window-frames, which are filled in with thick wooden bars set closely together.

Close to these three central towers is a cemetery for the dead with a little temple enclosed. There are also within the castle wall six or more large Yashikis, being the dwellings of the chief Samurai, or officers of importance, and their retainers. In addition, a large mound

commanding an outlook and several small Shintoo Temples, the principal one being dedicated to Haceman, the god of war. The outside wall, constructed in large polygonal blocks of stone and backed with earth, is interrupted at intervals by large gateway constructions. The ponderous wooden gates are hung to heavy square posts with thick lintels above. These gate posts, some eighteen inches square, often in pairs, are shoed and belted with bronze plates, mostly gilt and engraved. The gates too are generally adorned with metal fittings. The approach is by a permanent wooden bridge erected over the moat. Upon the surrounding wall, built out for the purpose so as to flank those who enter the gateways, are erected towers similar to the interior keeps, though somewhat smaller; and also at all angles of the wall are two-storied towers. Between these buildings and the gateways a low building or shed covers the whole top of the wall, taking the place of the hoarding to our mediæval battlements.

The temples of Japan are by far the most interesting and instructive buildings to be found in the country; set in the solemn shady quiet of their thick groves, approached by their avenues of lamps both stone and bronze; with the grand sweeping lines of the roofs projecting boldly forward, upheld by a profusion of brackets; wooden carving tastefully disposed, sharply and beautifully cut, and the whole woodwork often decorated in well harmonized colors with gilding and bronze ornaments. The principal temples are to be found in Nikko, Osaka, Kioto, and Tokio (or Yedo). The two principal groups of temples in Yedo are at Uyeno and at Shiba, and at both these places the large central temple has been destroyed by fire. The subsidiary temples, however, are so numerous and imposing, that these sites still rank first in importance in the city as temple groups.

The temples at Shiba are enclosed on three sides by a long wall with several gateways at intervals, and backed by a thick wood of fine old trees. The streets surrounding the walled sides consist of a continuous avenue of pine trees, interrupted only by one large and two small gateways forming the approach to the sacred grounds. The principal entrance is a large and imposing wooden structure some seventy feet wide and of about the same height. It is built upon heavy wooden pillars arranged so as to form one principal opening and two side ones; these wooden posts being tied together by horizontal beams tenoned to the posts, the sides of the entrances being filled in between this framework with panels of wood. Halfway up, above the soffit of the entrance, which is formed of heavy beams, a tiled roof slightly concave projects forward, and exhibits the ends and underside of numbers of rafters supported upon corbelled brackets. Above this roof the upper story is set a little back and surrounded by an open balustrade; this upper story is constructed of wide posts and horizontal beams with wooden filling in, crowned with a cornice of wooden corbels assisting to support the double rafters of the roof. This roof has the heavy appearance, the concave contour, and the semi-gabled form at the ends which is peculiar to all Buddhist temples in the country. After looking at other religious buildings where every part is painted, carved, or gilt, this gateway might be considered somewhat plain, as it has no carving, and is colored with one uniform dull red color; but it has more claim to grandeur of proportion and general effect than any other building which I have yet seen in Japan; its great size, good proportion, picturesque roof with ornamental crestings, also the numberless corbels, brackets, and rafters, some moulded at the ends so as to suggest the frowning face of a monster; also the deep red color, bright where the sun strikes it, and subdued in parts by the tree shadows and the sharp deep shadows of its cornices and roofs, all these help to fill the beholder with the liveliest feelings of satisfaction. Passing through this portal we find ourselves in a large open space some 200 feet square, in the center of which the large temple stood, now burnt to the ground. Across this space, nearly opposite to the great gateway, is a little temple approached by steps leading to a paved ante-court containing a few tombs and an image of Daibutz in bronze. This ante-court is defended towards the entrance by a screen and low gateway. The most noteworthy buildings, however, are on the right hand side of the open space just

referred to. These buildings consist of the shrines of the 2d, 6th, 12th, and 14th Shoguns and those of their wives, with the religious buildings attached. They were originally approached by two other gates, at some distance to the side of the great gateway which belongs to the large temple now destroyed, but these small gateways are now closed. They are very similar, and it will be sufficient to describe one. The entrance forms the center of three compartments divided by wooden pillars and connecting beams; the two side compartments form recesses for large wooden figures considerably larger than life, and indicative of exaggerated muscular strength and extreme hideousness. The face of one is painted bright red, and the other a livid green; the posts, wooden panels and gates are carved and colored in red, black, and gold, with diapers in color in some parts. The name given to the gate is Nio Mon (Mon-gate), Nio being the name of the hideous janitor who is supposed to guard the entrance to Buddhist sanctities, and whose representation is placed in carving on each side of these gateways. Within the Nio Mon an open space or court is passed, containing several rows of stone lamps, being large stone lanterns placed upon circular pillars with heavy bases moulded and carved, in all about five or six feet high. These were gifts from the smaller Daimios, being offerings to the Shoguns' shrines. Before some shrines there are long avenues of them, increasing in importance as they approach the temple. This court is enclosed by an ornamental screen fence, in which another richly decorated gateway, with heavy folding doors, leads to another court surrounded on three sides by a wooden screen wall carved and painted and protected by a tile roof.

Here are situated the large and elegant bronze lamps which were the dedication offerings of the great Daimios; and, placed in the same court to right and left, are two structures which are found in some form or other before all Buddhist temples of importance. The first or right-hand building consists of a large battering basement slightly concave and built in this case of stone in large courses, upon which is erected a wooden room of one story with a large roof, richly carved and colored roof rafters, brackets, posts, and panels; also an elegant balustrade carried upon projecting corbelled brackets. The ends of the rafters and the corbels of the wooden cornice are carved in the form of dragons and various beasts; and from the corners of the roof little bronze bells and pendant ornaments are suspended by chains. This is called the bell tower, and contains a large bronze bell which was struck formerly in time of war. At the bottom of this battering stone base is one of the few examples of stone carving actually forming part of a building that I have seen, consisting of panels carved with conventional flowers and foliage.

Facing this belfry, upon the opposite side of the court, is a large granite basin, about three feet six inches by eight feet, diminishing towards the base, where it is ornamented by means of a trefoil cusp form, cut out of the center of each side. It has also on one side two exquisitely cast bronze dragons of small size fixed into the stone, and serving as waterspouts. This basin is covered by a highly ornamental shed, consisting of a picturesque tile roof with gilt enrichments, supported upon angle posts sloping inwards towards the top, where they are tied by cross beams supporting brackets and carving just below the eaves. This shed is a beautiful example of Japanese decorative art. The posts are slightly moulded on the edges, and chiselled on the surface in a simple diaper of lines, the whole colored red. The cross beams which tenon into the posts apparently interpenetrate, their ends reappearing in a moulded form on the other side. They are decorated with a diaper of geometrical design composed of light colors, as are also the groups of brackets above. with the addition of much red and gold, The oversailing rafters of the roof are also richly colored in a similar way, and shoed at the ends with bronze gilt and engraved. The ceiling within is divided by ribs into square panels carved with flowers in relief, and colored with great delicacy and careful imitation of nature. At the further end of this court, where the largest and most ornate bronze lamps are placed, is a long roofed wooden building upon a stone basement, with a gateway in the center. This is the entrance of the cloister preceding the Haiden, as the temple we are approach-

ing is called. The long building is quite open on the inside, being a wooden cloister, or gallery, running parallel to the Haiden, from the center of which another cloister, open on both sides, runs at right angles to the entrance of the Temple. Towards the outside court this cloister presents a range of posts, connected by horizontal beams, filled in with wooden mouldings and carved panels. Above is a wooden cornice, with brackets and projecting roof. The whole being raised above the preceding court presents a stone basement some three feet high, in the center of which are steps leading to the entrance. The gateway is lower than the roofed cloister, but very imposing. The gate itself is placed between large posts flush with the side walls, but other posts are built out and connected with horizontal beams, so as to form the sides of a porch and support the overhanging roof. These sides are filled in, some distance from the ground, with thick panels of wood carved in the form of a writhing dragon of wonderful execution, cut right through so as to be viewed from either side. The wooden posts or columns of this porch are curved inwards towards the bottom and shoed with engraved bronze, placed upon a flat moulded stone base, somewhat similar to that of an Egyptian column. They are reeded, and curve in slightly towards the top, where they are also fitted with an ornamental metal socket. These pillars are connected by horizontal beams, apparently interpenetrating their surface, their moulded ends reappearing. The whole is crowned by the ordinary rich bracketed cornice and forest of rafters, and the ornamental tile roof in this case of double curve.

The gateway and whole range of buildings are beautifully colored, consisting of bands and small masses of light color and gilding upon a deep red ground. The posts, beams, and plain woodwork between the panels are red, with gilt bronze shoes, sockets, and belts. A little black is introduced in the form of framework within the main framework of the posts and beams, giving a sort of border to the red panels. In the center of the spaces thus formed is the raised moulded border, of curvilinear form, containing a panel of carving colored in whites, light blues, greens, purples, and other cool delicate tints. The beams and brackets of the cornice, and the under sides of the rafters, are decorated in light colored diapers, not unlike the mediæval European diapers found in roofs, ceilings, &c. Gilding is lavishly employed, blended with the colors in the diapers, and ornamenting the edges and mouldings of the beams and panels. On the inside, toward the Temple, the open cloisters are composed of richly carved, colored, and gilt posts and beams, with cornice and heavy roof. The center cloister leading up to the steps of the Haiden increases in height, its roof sloping upwards when the steps are reached until it intersects the principal roof.

The whole interior is low, but this is not always the case in Japanese temples, there being many instances of great interior height, though the entrances are indeed generally low. The floor is the only part which is not ornamented in some way, being covered with the ordinary rush mats; in this case, however, slightly wider than those used in houses. The steps between the rooms are of polished or sometimes of lacquered wood. The entrance is closed with heavy double doors, carved and gilt. The interior walls, where not interrupted by sliding doors and windows at the sides, exhibit the same framework of posts and beams, filled in with panels, and crowned with a cornice supporting the ceiling. The first rows of panels—those next the floor—are filled in with paintings upon a gold ground, representing in some cases large growing flowers and plants, and in other cases hideous imaginary animals. Above these the panels are carved in imitation of flowers and birds, such flowers as the lotus and botan (peony) being great favorites; the whole beautifully colored. The posts, slightly projecting beyond the panels, support corbels of wooden brackets forming a cornice, with intermediate brackets and paintings between. The framework is colored red and black, with many metal fittings.

The windows, which admit some light within, are small openings of many-curved outline, filled in with an open arabesque of wood or metal gilt, placed towards the outside, there being sliding shutters or paper windows on the inside to cover them, if needs be. The ceiling

is divided into small squares by ribs, lacquered black, with bronze sockets at the joints: these squares are painted and gilt in representation of dragons. All the painting is done with the most exquisite care and skill. On the outside there are carved panels of birds, plants, and flowers ranged in a line under the colored bracket, cornice, and rafters. The outside is colored red, relieved by the gold, bronze, and the light colors of the diapers and carving.

The roof is a fine example of the ordinary temple roof. It is composed of tiles, covered with thin plates of bronze, which have now assumed a dull gray of a slightly greenish tint. The tiles are alternately flat and semi-cylindrical, and the rolls thus formed along the roof are very effective, added to an ornamental ridge, and richly modeled and gilt terminals. The projecting edges of the tiles at the eaves are gilt, and the cylindrical tiles stamped with the Shogun's crest. The semi-gables which occur at the ends are filled in with carving and pierced wooden pendants, all colored in red or black, as the parts of the building. This Haiden is said to have been completed as recently as twenty years ago —about ten years before the revolution and the overthrow of feudalism in the country.

In addition to this Haiden, dedicated to the three Shoguns interred in the vicinity, we find, further situated to the right, three small Haidens, scarcely less elaborate, dedicated to each Shogun individually, erected at his death, and placed in front of the court preceding his tomb. These three courts behind the smaller Haidens are backed by a high retaining wall, faced with masonry set back, above which are the shrines. They are reached severally by a large flight of stone steps, projecting into the court below. The first reached is the shrine of the 6th Shogun, erected 170 years ago. It is entirely of bronze, and is by far the most handsome of the three. It is some ten feet high, composed of a circular drum with an enriched base upon a stone basement. It is rounded towards the top, and covered with a curved projecting roof formed of bronze, with little chains and bells attached at the corners. Upon the drum is the name of the Shogun sharply cast in the metal, as are also delicate mouldings and foliage, executed with great sharpness.

The whole is enclosed by a low, thick, bronze railing, with little bronze gates diapered on the surface with the favorite key pattern. The tomb is set back; and, in a line with the front of the wall, at the top of the steps, is a little gateway, with roof and double gates, all of bronze. The heavy gates are diapered with very shallow but sharp ornament; and the side wings, or walls, also of bronze, are ornamented with casts of two peacocks in low sharp relief. All the ornament is much more severe, more sparingly used, and the parts much heavier in proportion than the other tombs and their gateways, which are of stone and wood, and of later date.

At Uyeno, in the north of the city, there are the Haidens and shrines of the 4th, 5th, 8th, 10th, 11th, and 13th Shoguns, being grouped in threes, having one Haiden to each three, viz., the 8th, 5th, and 13th, and the 4th, 10th, and 11th. The arrangement is exactly similar to that of Shiba, but the stone and bronze lanterns are more numerous; the forms of the roofs, and details of carving, and mode of coloring are rather different. Black is much used in the decoration of these buildings at Uyeno. The outer gates are entirely black, with gilt and bronze ornaments, having the peculiarity of a roof covered with small wood shingle instead of tiles. Black is also much used in the decoration of the Haidens, which are otherwise richly colored, as at Shiba. The shrines of the 4th and 5th Shoguns are of bronze, with their railings, gates, and bas reliefs; the bronze has a dull greenish color approaching to black. Though the arrangements and general mode of construction of these sacred buildings are so similar that to describe each involves much repetition, yet there is such a variety of details—such different treatment in points of decoration, both carving and coloring—that there is in them an endless study for the artist.

The carving is generally cut in camphor wood, and the color is mixed with a kind of size which seems effectually to resist the action of the weather. The posts, beams and all large surfaces decorated in one color, are colored with the medium of lacquer; which is either left

of a dead color, or is polished to a great degree of brightness. The bronze shoes and other ornaments are deeply engraved and filled in with black in the hollows.

The Japanese sculptors divide carving into three kinds—shallow, deep, and pierced. In the earlier work, such as the bronze tombs and gates of the earlier Shoguns, the relief is very shallow—at the same time very sharp and effective. In the later work, nearly all carving upon the outside—such as in screens, gateways, and cloisters—is pierced in parts, being cut in a thick slab of wood, and can be viewed from either side. A striking thing in sculpture of this kind is the extremely careful imitation of nature, leaves and flowers being carved with a delicacy and truth to nature that is marvelous, and colored with the same care and beauty. Fruit is gilt, with red dashes of color showing the ripeness: and the greens in coloring the foliage are varied in their tone. Fore-shortening is frequent and well rendered; and though the Japanese artist does not seem to have understood the principles of perspective, which are often violated when dealing with representations of buildings and rectilinear forms, the perspective of all natural forms is carefully noticed and imitated. In Japanese theatre scenery I have also seen interiors of buildings represented correctly in perspective. The third kind of carving—the deep carving—occurs mostly in the interior of buildings when depth of effect is required, but at the same time no communication with the outer air which would be obtained if pierced carving were used. Beams and posts are often diapered with shallow incised carving, the key pattern being a very favorite one, sometimes with the stem and leaves of a plant intertwining. Posts are round, round and reeded, square, or square with the corner slightly rounded or moulded. They are rounded inwards and shoed with bronze, both top and bottom, and often a flat bell-shaped capital (similar somewhat to the Egyptian capital called "bell-shaped" by Mr. Fergusson, but flatter still) resting on a stone base of similar form at the bottom. The projections of interpenetrating beams are curled upwards and moulded, or are carved in the form of the fore parts of lions, elephants, or some animal real or imaginary.

In addition to the shrine temples at Uyeno there is a temple for public worship, called the temple of Gougen, of considerable size, though far inferior to the large temple burnt down during the revolution. It is approached under a Torii along a long paved path, with rude stone lanterns and large trees on either side: this leads to the raised stone platform, or court, which precedes the temple. This is approached by steps and protected by a wooden fence and gateway. This wooden fence is framed with posts and rails, dividing it into three rows of panels horizontally. The centre range is filled in with lattice work of an ornamental character, and the upper and lower ones with carving partly pierced, well-colored, and protected by a little tile roof carried upon a cornice of brackets. The gateway is rather higher than than the fence, being covered with an elegant roof of double curve. In this inner court there are elegant bronze lamps; the largest and most ornamental being placed on either side of the steps leading up to the temple door. The temple is nearly square in form, with a small projection at the back containing a sacred shrine. The whole is carved and colored both on the interior and the exterior, the constant use of black and red being noticeable, and carving mostly in light colors.

There are a great many Shintoo temples in the country; the principal one at Yedo being the Kudanzaka. The temple grounds are open, and not surrounded by a grove, as are the principal Buddhist temples; they are entered under a structure found before all Shintoo temples, called a Torii. It is composed of two upright posts of great thickness, generally consisting of the whole trunk of a tree rounded, about 15 feet high, and placed 12 feet apart. Across the top of these a wooden lintel is placed, projecting considerably, and curving upwards at the ends; some few feet below this another horizontal piece is tenoned into the uprights, having a little post in its centre helping to support the upper lintel. These Torii were originally of wood, as is the one at Kudanzaka; but when found before Buddhist temples, which is not unusual, they are mostly of

stone, always showing, however, by their joints and general construction a decidedly wooden origin.

The temple itself is a simple oblong plan, with steps leading up to the entrance, and to an exterior gallery running all round. The roof differs from the roofs of Buddhist temples in being flat and not curved on its sloping surfaces, which are rather steep, and project considerably at the eaves, and in two gable ends. The roof is covered with wood shingle, stained of a dark grey color. At the gable ends there are cross timbers in the shape of the letter X; straddling the roof also at intervals along the heavy ridge, apparently balanced across it are curious beams some 6 feet long, tapering towards the ends. The whole appearance is extremely heavy and curious, and the peculiar forms, such as the cross pieces and beams crossing the ridge, seem to indicate its affinity to the original thatched roof. In some parts of the country the Shintoo temples are still covered with thatch. The construction of the walls of the temple is in the main similar to that of the Buddhist temples, but the wood is uncolored and sparingly decorated with carving. The projecting rafters and ends of beams are generally carved. Color as an exterior ornamentation is by no means found in all temples, even of Buddhist religion.

There is a temple at Asakusa, in Yedo, which is called Honwanji, and which is, I believe, the largest building in the city; but though remarkable for its great size and height, and for the quantity and exquisite workmanship of its carvings, is entirely devoid of color on the exterior, and the wood has assumed an ashen grey. It is almost square, and is surrounded by a gallery reached by steps, which are roofed over, the posts supporting the roof being shoed with bronze, and the beam ends carved into monsters, lions or elephants. The gallery floor is supported upon brackets, which spring from the base of the walls of the temple very near to the ground. Numerous beam ends, rafter ends, brackets, and supports are carved into the most delicate representations of flowers, plants, and birds in sharply cut carving. The roof of the temple rises to a great height. The interior is decorated in color, and, on account of the great span of the roof, there is a peristyle of columns assisting to support it, upon which are groups of corbelled brackets blending with the design of the paneled ceiling. These brackets correspond to similar ones placed round the walls in the cornice over pilasters. The ordinary panels of colored carving are to be seen below.

Yedo and its immediate neighborhood contain some twenty-seven temples of importance, besides many other smaller ones as numerous as London parish churches. To describe properly and fully one temple group would require a Paper to itself.

SPRINGS.

By ARTHUR DE BONNEVILLE, Jr., Class of 1878, Stevens Institute of Technology, Hoboken, N. J.

Contributed to VAN NOSTRAND'S MAGAZINE.

II.

SOLID BLOCKS USED AS SPRINGS.

MATERIAL.— The springs under this head are made of india rubber, of which immense quantities are imported. From two or three hundred tons in 1830, the importation of caoutchouc into the United States and Great Britain had increased to over one hundred thousand tons in 1870, and to a valuation of many millions of dollars; and the demand is still increasing, as is the variety of its uses, and the forms of its manufacture.

THE RUBBER YIELDING TREE is found in all parts of the world within the limits of the belt formed by the tropic circles—in South America, Mexico, Panama; in equatorial Africa, Madagascar, British India, Burmah, Siam, Borneo and other islands of the Pacific.

The Brazilian caoutchouc (known as

Paran from the port of shipment) is by far the best and most abundant. The tree is of immense size, frequently of over one hundred feet in height and of a girth in proportion. The monarch of the forest where it is found, its lofty and dense crowns are visible for miles away, giving a grandly picturesque character to the naturally beautiful scenery. The tree is tapped after the manner of tapping the sugar maple in this country. The sap is caught in small vessels and, when gathered in sufficient quantities, is dried and stiffened without delay in the smoke of the nut of a species of nut palm* found in the neighborhood. If not done at once the resin separates from the sap.

The sap gatherer dips his wooden shovel into the white fluid and holds it for a moment in the smoke, or till it becomes of a grayish yellow color and firm and stiff, then he dips it in again, and again holds it over the smoke, and so on till the layers have become six or eight inches thick; the mass is then removed by a knife from the shovel and hung up in the sun to let the water dry out from between the layers.

The color is at first of a steel gray, but soon becomes darker from exposure, and appears as we are accustomed to see it in the crude form known to commerce.

This coagulating process could be much simplified by the use of alum, or the sap could be kept in the fluid state by the use of ammonia, and sent to market in casks (and indeed it is so sent now in some cases), but as long as the gathering of it remains in the hands of the rude natives, the old and tedious process of smoking will without doubt be adhered to; even in this crude fashion a practiced hand can prepare for market five or six pounds per hour. Their unskillful and wasteful methods, however, are fast destroying the trees and annihilating the sources of supply so that serious apprehensions are entertained, and anxious attention is directed to hunting out new sources, and planting and nursing young forests to fill up the gaps created by the wastful energy of these unskillful and unthinking natives.

* There are twenty varieties of these beautiful palms in the Amazon Valley. They yield a black fiber called *Piassaba*, which makes excellent cordage. The nuts are excessively hard and beautifully mottled with dark brown.

In the East the process is even more crude than this; the milk is allowed to flow into holes made in the earth at the roots of the trees, and is gathered on earthen moulds into balls and bottles, etc.; the earth being afterwards removed by crushing and softening it in water. The rubber is of lighter color than the American, on account of its being dried in the sun, but contains much more extraneous matter which has to be removed in the subsequent preparation of the material, and is, consequently, of less price in the market.

The older the tree, and the warmer the weather, the richer the juice. More recently there has been found in the East a clinging vine that affords a good yield of caoutchouc: the lettuce, the poppy and some of the Euphorbia are said to produce it as well as other plants having a viscid, milky sap.

Properties.—The properties of india rubber are well known; the most useful are its elasticity, softness, and indifference to water and acid, though the latter is not absolute; caustic alkalis have absolutely no effect upon it. It is, however, very sensitive to cold and heat, which destroy its usefulness: at the freezing point of water it becomes rigid and unyielding, and at a high temperature it becomes viscid, offensive and useless: hence the necessity of overcoming these native defects by means of the manipulations which are described below.

It has been observed that when a piece of rubber is suddenly stretched it becomes warm and electrically excited. By digesting it in warm water it may be extended to seven or eight times its original length, without having its contractive powers destroyed. Submitted to severe cold it becomes rigid again and more opaque than when heated. The same results are obtained if the substance remains for a long time in a state of rest, but the original properties are again restored upon the application of a moderate degree of heat.

As stated by Ure and others, the caoutchouc when stretched as above, and suffered to remain in that state for such a length of time as will suffice to destroy its elasticity, increases its density, being under these circumstances 0.9507, whereas, when the elasticity is restored by

heat, the specific gravity decreases to 0.9257.

FORMS OF RUBBER SPRINGS.

One of the earliest uses of rubber in springs was made by forming it into a sort of air-tight rectangular, hollow chest, confining the amount of air requisite to fill it, and thus forming a sort of cushion or pillow: when under pressure the air and rubber jointly act as a spring.

AGAIN, A SHEET OF RUBBER was placed between two plates with cogged teeth: under pressure the teeth of the upper plate would tend to press themselves into the spaces between the teeth on the lower plate, the rubber between the teeth thus being subjected to a tensile strain.

A CYLINDER OF RUBBER was circumscribed by a cylindrical piece of metal which was opened by a longitudinal cut, to each of whose sides was attached a straight arm. By this means the rubber could be clamped, it thus acting as a spring to throw open the arms.

A METAL CYLINDER closed at one end and into which another cylinder slid concentrically, and filled with small pieces of rubber, as was also the sliding cylinder, has been made to act as a spring. A ball or sphere can be substituted for the small pieces of rubber.

THE MOST COMMON FORM in which rubber, at present, is used for a spring is cylindrical or barrel-shaped.

RAILWAY BUFFERS are furnished with a series of washers about two inches in thickness, separated from each other by sheet iron plates which allow each washer to be compressed singly, so that every advantage is used and derived from the characteristic properties of the material. To allow the passage of the buffer rod, these washers are pierced in the center with a hole, the diameter of which is larger than that of the plates, so that the depression of the washer may not drive back the rubber against the rod; for the same reason the iron plates are of large dimensions to prevent the rubber from being pressed back beyond the outer edges.

BEHAVIOR OF THE RUBBER.—The laws of the action of rubber under loads have not been sufficiently investigated to give general formulae for construction in this material.

The form of the cross-section for rubber rings of buffer springs is represented by the accompanying figures.

They have at the upper surface a ring running all around, and at the lower surface a corresponding depression into which the interposing plates fit. For the behavior of such and similar pieces we have the following. The shape of the cross-section of the spring before compression is A B C D, afterwards it is represented by *a b c d*.

The limit of elasticity is reached approximately by a load of $\frac{1}{2}$ ^{k} per $\square$ ^{mm}, the load being, before compression, on a section normal to the axis. This calculated bearing capacity is somewhat greater (up to 55^{k}) for the lighter, and somewhat lower (up to 45^{k}), for the heavier kinds of rubber.

The specific gravity of the material varies with the quantity of sulphur incorporated; for the lighter 1, for the heavier 1.15 to 1.32.

The amount of compression within the elastic limit, depends upon the quality of the caoutchouc, and for the metrical system is approximately

$$\lambda = \frac{l}{\gamma}\sqrt{\frac{P}{g}};$$

where λ equals the compression, P the force, g the original cross-section in a plane normal to the axis, γ the specific gravity of the material, l the original thickness of the rubber.

EXAMPLE.

A buffer of the form represented in Fig. 7; having an outer diameter of 74^{mm}, a cross-section g equal to $11536\,\square^{mm}$, l being equal to 35^{mm} and γ amounting to 1; was subjected to a load of 2500^{k}.

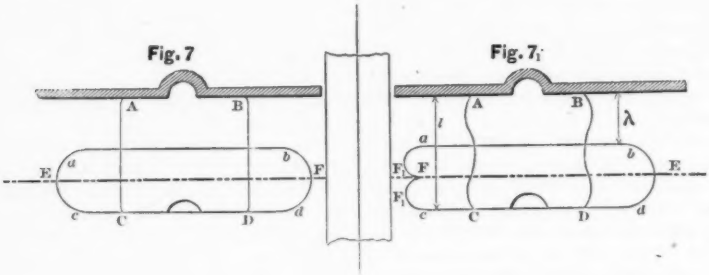
The load then for a unit of surface for the original cross-section is $P = \frac{2500}{11536} = 0.217^{k}$, and according to the formula $\lambda = 35\sqrt{0.217} = 35 \times 0.466 = 16.31^{mm}$. Experiments on the same ring gave $\lambda = 16.75^{mm}$.

On railway buffers of this kind from four to seven rings of the above dimensions are used. The total compressibility is evidently obtained by multiplying the compression of each ring by the number of rings.

In the practical use of caoutchouc buffers we often find that they soon lose their elasticity and that ultimately the

rubber is transformed into a hard and brittle mass. This only happens when the material is subjected to abrasion. To provide against this the plates of iron should project outward and inward so far over the rubber ring that by its compression never touches the center rod or the outer box.

It is advisable to so choose the form of the rings that the formation of folds



is impossible, as they soon destroy the rubber. Such folds are easily formed with rings of the section shown in Fig. 7_1, as is represented at F_1 F_2. The rings of rectangular cross-section are free from this fault and therefore vastly to be preferred. (*Der Constructeur, Reuleaux*).

MANUFACTURE.

As the raw material has first to be gotten into a shape fit for the manufacture of the springs, we will give an account of all the preliminary processes employed, and will follow the spring until it appears in the market a finished article.

WASHING AND CLEANING.

The rubber as received from the gatherers is in all shapes, colors, and conditions, full of dirt, sand, the *débris* of the forest, unsightly and nasty. It is first thrown into tubs and softened with hot water and steam. Then put between two smooth iron rollers which mash and soften it still more, while water trickling down on it from above washes away much of the dirt loosened by the rollers.

After this process has been repeated several times till all the dirt and sand is supposed to be washed away it is taken to another set of rollers, with spirally corrugated surfaces, or with teeth of one fitting into sockets in the other, which thoroughly masticate and grind it up into a shapeless mass, while the water which has all the while been trickling through it has washed away the remaining impurities and it is pronounced clean.

DRYING.

The next process is to dry it in a room heated by steam; and the longer the better, as the best article is, and should always be, entirely free from water. This takes from three to four months; then comes grinding or

KNEADING.

This is done by a pair of steam heated rollers by which the rubber, passing between them again and again, is softened and kneaded through and through till it becomes of about the consistency of putty or dough, and is then rolled into sheets.

MIXING.

It is now in a condition fit for the manipulation of the manufacturer of the springs. This is done by adding to the material, in the condition described, mixtures of various substances which vary with the manufacturer.

These mixtures consist of flowers of sulphur and other ingredients to give color, body and softness, litharge, white lead, zinc white, whiting, &c. The sheets are passed repeatedly through the steam heated rollers while the compound is sprinkled on, or laid on with trowels made for the purpose, until the mixture is thoroughly incorporated with the rubber. It is now soft, pliable and of a whitish color.

CALENDERING.

The calender now takes the rubber sheets and rolls them to the proper thickness. Machines for this purpose are manufactured at the National Iron Works, (New Brunswick, N. J., Wm. E. Kelley, proprietor). Generally, they are made with three rolls; some are made with four or five rolls, weighing sixty thousand to seventy thousand pounds, the rolls being twenty inches in diameter and sixty-two in length. The distance between them can be regulated to any thickness of rubber. The machines are fitted with spiral connecting gears, preventing back lash and consequently producing sheets without marks or wrinkles.

CURING OR VULCANIZING.

To make the compound chemically, as well as mechanically, unite with the rubber, *i.e.*, to cure or vulcanize it, it is passed into ovens heated to 250° to 300° Fahr., where it remains from two to four hours, depending upon the thickness and the elasticity desired.

MAKING THE SPRING.

When the rubber sheet comes from the calender rolls it is wound on a mandrel, the diameter of which fixes the center hole of the spring. To wind it on this iron rod we proceed as follows: first, rubbing on a little soap stone to prevent sticking, a short piece of sheet rubber is taken, of a length sufficient to cover the mandrel, and of a breadth sufficient to envelop the rod. The joint is fastened by a layer of thin rubber the entire length of the sheet, thus forming a tube on the mandrel. The continuous sheet is now wound directly on this tube to the desired thickness. If the spring is to be barrel shaped, it is made so, roughly, by trimming it with a knife to the required shape. Lastly, it is put in an iron mould and placed in the steam heater for vulcanizing. The mould of a six-inch spring is a hollow iron cylinder, whose outside and inside radii differ by one and one-half inches. It is two feet high, has a cap one and one-half inches thick, and has one end closed. The cap is fastened to the top by two bolts, one inch in diameter. To vulcanize a six inch spring it must be subjected to 255° Fahr., for four hours.

PART SECOND.

TESTS OF SPRINGS.

In part first were given methods, by means of which springs are tested to determine any want of elasticity, on account of which they would be rejected.

The following is the method pursued in testing a number of springs to determine their laws of resistance, so as to be used for dynamometrical purposes.

The first requisite was a testing machine. The Mechanical Laboratory of the Stevens Institute of Technology contains a machine for testing materials transversely. It is represented in the figure and consists essentially of a mechanism for applying the power or transverse stress, upon a test piece L, and a recording apparatus (not in the figure) by means of which this stress can be accurately determined. The bed-plate of the machine carries a vertical rod to which is clamped a bracket used for the support of a small micrometer screw, having forty threads to the inch, and whose head is graduated into 250 divisions, thus enabling it to measure $\frac{1}{10{,}000}$ inches accurately.

To insure accuracy, electric contact is made between the micrometer screw and the test piece: by means of an electric battery of small power, one wire of which is connected with the micrometer screw, and the other to the cross head which abuts against the specimen.

The current also flows through a small electric bell; upon closing contact between the micrometer and cross head the bell rings.

The pressure brought to bear upon the test piece is communicated through the cast iron support D to the bed-plate, and this affects the scale beam, thus indicating the stress applied.

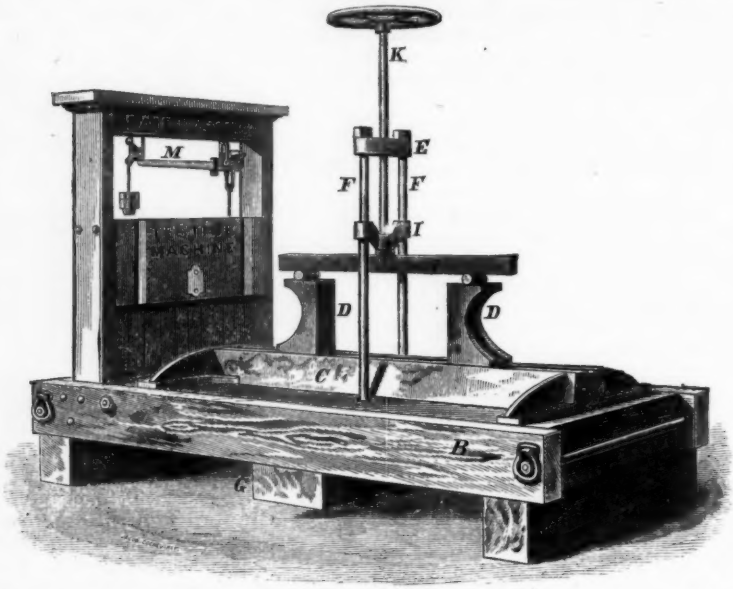
The supports, the tops of which are on the same level, are twelve inches high.

Upon each of these is placed a roller one and five eighths inches in diameter, which are used to ease off the specimen.

The supports themselves rest in a guide groove V cast upon the bed plate; the intermediate distance between them can thus be varied to suit any length of specimen.

The bedplate C is in the form of a cast iron I beam and is firmly secured

FIG. 8.



to the platform of the scale. The square-threaded screw K by means of which the pressure is applied has four threads to the inch and works in a large nut E, supported by two vertical columns, F. These columns are one and eleven-sixteenth inches in diameter and are secured beneath the platform of the scale to a large heavy oak beam G by means of two large washers and nuts.

This beam is forty-six inches in length, eleven and one half inches in breadth, and five and one half deep.

The two columns act as guide rods for the cross head I, with which the end of the screw is provided.

TELEMETER.

To test the springs, to determine their laws of resistance it was found that the small micrometer could not be well used as a measuring apparatus; for the cross head of the testing machine, which slides on the columns for guides, could not be made to abut against the top cap of the spring. The cross-head was taken off the machine and the end of the screw was made to abut against the bottom of a cavity made in the top cap of the spring. On the ring of the hand wheel O two grooves were turned, one on the upper and one on the lower part of the periphery, so as to be able to turn a cylindrical surface on which divisions were graduated. A vertical scale was also added. The apparatus was thus converted into a TELEMETER.

Before using the readings as given by the telemeter, the accuracy of the machine had to be tested; for, under the changed conditions, the deflections were measured by means of the large square-threaded screw before they were measured by the small delicate screw of the micrometer, with electric contact. Errors occasioned by the springing of parts of the machine were taken into account. The testing for accuracy was conducted as follows:

1. By subjecting the apparatus uniformly to an increasing pressure, the rate of increase being one hundred pounds.
2. By increasing the pressure at one-half that rate that is to say fifty pounds.
3. By increasing the pressure variably.
4. By testing without pressure.
5. By taking the screw off the machine and noting its inaccuracies, by placing a scale along side of it.

The first four tests of the machine were made by comparing the readings of the telemeter with those obtained with the small micrometer screw. The method of procedure for the first three was as follows: A bar of wrought iron was placed on the rollers of the transverse machine subjected to a certain pressure, and the deflection as given by the telemeter was noted; a reading was next taken by means of the small micrometer and the difference between the two gave the error. The comparison was made by taking the advance of the cross head for the advance of the screw.

This would be correct if the cross head slid with perfection on the columns: but that is not the case on account of the imperfection of workmanship. If a reading is taken by means of the small micrometer screw, and a second reading is taken, the cross head having been slightly tapped, a difference will be found when reading down to ten thousandths.

Another method that would have given more perfect results would have been to fix the small micrometer screw so that its axis coincided with the axis of the large screw and abutted against its upper head, but this was inconvenient.

The fourth method was to measure the ascent or descent of the cross head by means of the micrometer, and compare it with the ascent or descent as measured by the telemeter.

The fifth method gave results which differed somewhat from the fourth, but the difference is very small: the method of procedure was to count one hundred and twenty threads on the large screw. They should measure thirty inches; for there are four threads to the inch, but observation showed a lack of .04 of an inch; so that the error for one thread is $\frac{.04}{120}$. The results of the tests by means of the small micrometer are somewhat greater. This increase of error obtained by testing the separate parts or threads may be due to the fact that the threads, from wear, have become thinner without evidently altering the length of the whole screw.

It may be stated that when operating with the testing machine, care should be taken not to subject it to any shock. A person walking near the machine may produce an error in reading. No pressure should be exerted on the hand wheel and small micrometer: in the former case the equilibrium of the beam of the scale will be disturbed; in the latter, contact will be made before the proper advance of the micrometer screw.

The conclusions of the test are that the main error is due to the springing of parts of the machine, that it is a function of the pressure, the error being .005 of an inch for one hundred pounds; that the errors are very small, and that on the whole the telemeter is accurate enough for practical purposes.

FURTHER ARRANGEMENTS.

A casing was necessary in which the spring was placed to keep it in its proper figure—a wrought iron pipe with an outside diameter of three and a half inches and inside diameter of three and one-eighth inches, one end being closed—length of about twenty-three inches. To keep this casing of the spring in its proper position, a wooden support was fitted on the pipe, it fitting also in the column of the transverse machine. A slot was cut into the pipe of about four inches in length and one-eighth inch in breadth, for the purpose of observation while the experiment is going on. The outside and inside surfaces of the closed end of the pipe were made parallel by turning them in the lathe.

MANUFACTURE AND DIMENSIONS

The springs were made by Vose, Dinsmore & Co., by heating the steel so that it could be easily wound upon a mandrel, whose diameter equals one and one half inches. They were tempered by plunging them into an oil bath, after coming from the coiling machine, and keeping them there about six seconds, after which they were plunged into a tank of water for about two seconds. The oil bath is kept approximately at its proper temperature by being placed in a tank through which there is a constant flow of water. Before leaving the factory the springs were subjected to the greatest pressure under which they were to be used. The springs are each fitted with two cast iron caps, one is used as a base, and by means of the other, the spring is subjected to pressure. The base cap of the spring was put into a

lathe and its lower surface turned so that the axis of the spring is vertical when supported by the cap. The upper cap is bored out so as to admit the end of the screw of the transverse machine which exerts the pressure. The boring is about one-quarter inch deep and is concave on its base surface. The section of the wire of the coils is a circle, the diameter of which is five-eighths of an inch; the length of the springs originally was eighteen and one-quarter inches, the number of coils of each is nineteen and one-quarter, and each spring weighs twelve pounds.

DETERMINATION OF THE LAW OF RESISTANCE.

Spring No. 1 was tested

1st, at the common temperature.
2d. " " freezing point of water.
3d. " " boiling " " "

MANNER OF TESTING.

The spring with its casing was placed on the bed-plate between the columns of the machine in line with the axis of the screw; the scale beam was balanced and the hand-wheel turned until the end of the screw just touched the bottom of the cavity made in the top-cap; when the screw through the cap subjects the spring to the slightest pressure it is indicated by the scale-beam; the reading of the telemeter is now taken. The hand-wheel is turned till the scale beam is balanced for an increase of one-hundred pounds pressure and the reading taken; the difference between the two readings gives the deflection for one-hundred pounds which is too great by .005 of an inch, and this amount was subtracted to get the true deflection. The figures in the tables are deflections for increments for two hundred pounds.

At the ordinary temperature the testing was conducted by increasing the pressure uniformly at the rate of one-hundred pounds up to 5,000 pounds at which point the coils were not entirely closed.

The spring was subjected to pressure until the set for five thousand pounds was inappreciable. The set for the test when the table was obtained equals $\frac{1}{64}$ inch.

The results obtained by the experiments show that the deflection under a constant, increasing pressure is approximately constant. The valuation, therefore, between the different pressures and deflections will be represented very nearly by the hypothenuse of a right angled triangle of which the altitude equals the total deflection and the base, the total pressure.

SPRING No. 1.

Pressure. Pounds.	Increment of Deflection. Inches.	Total Deflection. Inches.
200	.169	.169
400	.165	.334
600	.163	.297
800	.164	.664
1000	.163	.824
1200	.160	.984
1400	.164	1.148
1600	.163	1.311
1800	.167	1.478
2000	.161	1.639
2200	.163	1.802
2400	.173	1.975
2600	.161	2.136
2800	.171	2.307
3000	.170	2.477
3200	.169	2.646
3400	.164	2.810
3600	.165	2.975
3800	.165	3.140
4000	.162	3 302
4200	.159	3.461
4400	.163	3.624
4600	.151	3.775
4800	.125	3.900
5000	.087	3.987

SPRINGS NOS. 2 AND 3.

Spring No. 2 originally measured $18\frac{1}{8}$. It was pressed home, allowed to remain with its coil closed for five hours and then relieved. It had taken a set of $1\frac{1}{32}$ inches. It was then subjected to a pressure of 5000 pounds for intervals of time, as in the table.

In the 1st it set $\frac{1}{32}$ of an inch in 18 hours.
" 2d " $\frac{1}{16}$ " 14 "
" 3d " $\frac{1}{32}$ " 14 "
" 4th " $\frac{1}{64}$ " 14 "

Spring No. 3 behaved in the same manner. The table of sets shows that the rate of decrease is one-half when the equal loads act for equal lengths of time.

After the springs were tested for sets, the law of resistance was obtained, as given in the tables. Two tests were made, A and B. A was made first, and

after relieving the spring of all pressure, B was obtained.

SPRING No. 2.

Pressure Pounds.	A. Increment of Deflection. Inches.	A. Total Deflection. Inches.	B. Increment of Deflection. Inches.	B. Total Deflection. Inches.
200	.191	.175	.175	.175
400	.171	.362	.175	.350
600	.175	.537	.171	.521
800	.168	.705	.174	.695
1000	.176	.881	.173	.868
1200	.170	1.051	.170	1.038
1400	.169	1.220	.171	1.209
1600	.168	1.388	.170	1.379
1800	.174	1.562	.168	1.547
2000	.171	1.733	.193	1.740
2200	.172	1.905	.176	1.916
2400	.173	2.078	.174	2.090
2600	.168	2.246	.168	2.258
2800	.183	2.429	.182	2.440
3000	.189	2.618	.171	2.611
3200	.181	2.799	.189	2.800
3400	.196	2.995	.198	2.998
3600	.184	3.179	180	3.178
3800	.143	3.322	.154	3.332
4000	.085	3.407	.070	3.402
4200	.087	3.444	.065	3.467
4400	.017	3.461	.012	3.479
4600	.022	3.483	.010	3.489
4800	.008	3.491	.007	3.496
5000	.009	3.500	.005	3.501

(*Spring No. 3 on following column.*)

SPRING No. 4.

Pressure Pounds.	Increment of Deflection.	Total Deflection.
50	.093	.093
100	.094	.187
150	.109	.296
200	.047	.343
250	.094	.437
300	094	.531
350	.094	.625
400	.062	.687
450	.094	.781
500	.094	.875
550	.093	.968

VERIFICATION OF RESULTS.

To check the results obtained, as given in the tables, formulæ were used which gave the laws of deflection.

Rankine gives the formulæ $\frac{W}{v}=\frac{cd^4}{64nr^3}$,

SPRING No. 3.

Pressure in Pounds.	A. Increment of Deflection. Inches.	A. Total Deflection. Inches.	B. Increment of Deflection. Inches.	B. Total Deflection. Inches.
200	.185	.185	.185	.185
400	.165	.350	.166	.350
600	.164	.514	.166	.517
800	.167	.614	.164	.681
1000	.164	.845	.164	.845
1200	.164	1.009	.166	1.011
1400	.167	1.176	.164	1.175
1600	.168	1.344	.169	1.344
1800	.166	1.510	.168	1.512
2000	.168	1.678	.163	1.675
2200	.169	1.847	.173	1.848
2400	.177	2.024	.169	2.017
2600	.166	2.190	.166	2.183
2800	.185	2.375	.179	2.362
3000	.181	2.556	.174	2.536
3200	.182	2.738	.172	2.708
3400	.195	2.933	.178	2.886
3600	.188	3.121	.180	3.066
3800	.167	3.288	.165	3.231
4000	.109	3.397	.107	3.338
4200	.062	3.459	.070	3.408
4400	.057	3.516	.053	3.461
4600	.042	3.558	.034	3.495
4800	.021	3.579	.028	3.523
5000	.020	3.599	.019	3.542

SPRING TESTED BY THE MECHANICAL LABORATORY

The diameter of the wire equals $\frac{3}{16}$ of an inch; the length $3\frac{1}{16}$ inches; the number of coils 14: diameter of spring $\frac{7}{8}$ of an inch.

where r equals the radius of the cylinder containing the helical center line of the spring as measured from the axis to the center of the wire, n the number of coils of which the spring consists, d the diameter of the wire, c the coefficient of the rigidity or transverse elasticity of the material, w any load not exceeding the greatest safe load, v the corresponding extension or compression; then for springs No. 1, 2 and 3,

$$\frac{100}{v}=\frac{11{,}000{,}000\times\frac{625}{4096}}{64\times19\times1.19}$$

$$\therefore\ v=.086;$$

for spring No. 4

$$\frac{50}{v}=\frac{11{,}000{,}000\times\frac{81}{6561}}{64\times14\left(\frac{11}{32}\right)^3}$$

$$v=.11$$

Clark gives $E=\frac{d^3\times w}{D^4\times C}$; in which E equals the compression or extension of one coil in inches; d, the diameter from center to center of steel bar composing the spring in inches; w, the weight applied in pounds; D, the diameter or side of square of the steel bar of which the spring is made in 16th of an inch; C, a constant which from experiments may be taken as 22 for round steel and 30 for square steel. The deflection for one coil is to be multiplied by the number of free coils, to obtain the total deflection for a given spring. For springs Nos. 1, 2 and 3,

$$E=\frac{10.594\times 100}{(\frac{9}{8}\times 16)^4\times 22}=.0048$$

$$.0048\times 19=.0912 \text{ Ans.};$$

for spring No. 4

$$E=\frac{(\frac{11}{16})^3\times 50}{(\frac{3}{16}\times 16)^4\times 22}=.00828$$

$$.00828\times 14=.12 \text{ Ans.}$$

With reference to the formulæ, we conclude that the one given by Rankine is very approximate. Clark's formulæ gives a result somewhat too large. If the constant is 25 instead of 22, for round steel, it will better agree with the table formed by the experiments.

TEMPERATURE TESTS.

To surround the pipe with ice, a casing of wood with a bottom of tin was made, a section of which, perpendicular to its longitudinal axis, is eight inches square. In the pipe, two holes were drilled, one at the upper and one at the lower end. The holes were tapped, and two $\frac{3}{8}$ inch pipes were screwed into them, the office of which was, to hold two thermometers that noted the temperature of the spring, and were long enough to reach through the ice casing, which had two corresponding holes for the admission of the pipes.

While testing, ice was also let into the main pipe, which extends above the spring, thus surrounding the lower part of the screw of the telemeter, and producing a continuous packing of melting ice upon the spring, besides that which surrounds the pipe.

The test in steam was conducted by generating steam in a small copper boiler, and conducting it through a rubber tube, to the large pipe, by attaching it to one of the small pipes that are screwed into the casing, the steam escaping through the other small one. The space between the screw of the machine and the pipe casing was stuffed with ordinary waste, to prevent the escape of the steam. Through this stuffing a thermometer was put to note the temperature.

From the results of the investigation nothing definite could be determined, as to any change of the law of resistance, as given by the common temperature tests. The only change found, was in the sets. The spring when in ice and subjected to a pressure of 100 to 5,000 lbs., five times, set $\frac{3}{16}$th of an inch. In steam, subjected to the same pressure, the same number of times, it gave a set of $\frac{1}{64}$ of an inch.

At a recent meeting of the Royal Society of Edinburgh, Sir W. Thomson gave some explanation of the telephonograph. All previous attempts to record sound were, he said, founded on the motion of a style or marker at a true parallel to the paper. Mr. Eddison's ingenious invention of the electric pen was different. It consisted of a fine point, which, by an excessively rapid vibration perpendicular to the paper, caused by a small electric machine connected with two thin wires to the point, left a trace of any person's handwriting in a row of very fine holes, from which the handwriting could be printed. Mr. Eddison, from this invention, elaborated the phonograph. By the greater or less pressure produced through the action of the alternate condensation and expansion of the air caused by the mechanism of the voice, the diaphragm operated upon the point and recorded the sounds. It was the most interesting mechanical and scientific invention they had heard of in this century. There could be no limit to its application. A man could speak a letter through the phonograph—it would be recorded on tinfoil, sent in an envelope through the post, and his friend, by applying the point of the phonograph to the tinfoil, could reproduce the words and tones uttered.

MOMENTUM AND VIS VIVA.

By J. J. SKINNER, C. E., Ph. D.

Written for Van Nostrand's Magazine.

In the May number of this Magazine, Mr. S. Barnett, Jr., begins a review of my articles of November and December, 1877, by saying that the mistakes into which I have fallen arise principally from two causes; the chief one, so far as concerns the reader now, being stated to be a misunderstanding of the question to be solved in establishing an absolute unit of force. A decision as to whether my main opinions are mistakes or not will be made for himself by each reader who has taken the trouble to follow the discussion. It will be permitted to me to examine here whether the articles referred to show the alleged misunderstanding of the question to be solved in establishing an absolute unit of force, and also to consider a few minor points of the criticism.

My reviewer seems to have entirely, and to me unaccountably, mistaken the tenor of my remarks on the "absolute" unit of force. On p. 464 he attributes to me the raising of objections to the "absolute *measure of force;*" but I have raised no such objections whatever. On the contrary, I gave at the top of p. 421, Vol. XVII, the rule by which the so-called "absolute" unit of force is defined, viz: "that force which by acting for one unit of time on one unit of mass shall give it one unit of velocity," and stated that there is *no* objection to this method in itself; and on the next page I explained how a balance giving such a unit of force could be graduated in a particular place, if any motives of convenience should make it desirable to use that unit. What I did object to, and what I still think is absurd, is the application of the word *absolute* to the particular unit of force under discussion.

But besides charging me with raising objections to a particular *measure of force*, when I was merely discussing the propriety of a name, Mr. Barnett is apparently talking about one "absolute" unit of force, and I about another. For he would begin (p. 464) by making his units of time and length depend on the time of vibration and length of wave of a particular kind of light, and then "define the unit of *mass* by its relation to that mass which, by its attraction of gravitation, at unit distance, will produce unit velocity in unit time." Now a unit of mass might theoretically be so defined; but the unit of mass actually taken by those who give the above definition of the "absolute" unit of force, is not determined by any such relation. Thomson and Tait, Nat. Phil., Vol. I, speak as follows on this point:

Art. 221. "It is therefore very much simpler and better to take the imperial pound, or other national or international standard weight, as the unit of mass, and to derive from it, according to Newton's definition above, the unit of force. This is the method which Gauss has adopted in his great improvement of the system of measurement of forces; and by it we have, *and by it only can we have*, an *absolute unit* of force.

Art. 225. "The unit of mass may be the British imperial pound. We accordingly define the British absolute unit force as the force which, acting on one pound of matter for one second, generates a velocity of one foot per second.

Art. 412. "The British unit of mass is the Pound (*defined by standards only*)."

Prof. Clerk Maxwell, *Matter and Motion*, 1876, p. 41, says:

"The unit of mass in this country is defined by the Act of Parliament (18 & 19 Vict. c. 72, July 30, 1855) to be *a piece of platinum* marked 'P.S., 1844, 1 lb.,' deposited in the office of the Exchequer."

My reviewer, p. 464, says that it is hopeless to expect to establish any invariable units dependent upon aggregations of matter. But if the above definitions do not make the ordinarily so-called "absolute" unit of force, depend on a particular aggregation of matter it would be hard to find any unit that is thus dependent. And it is precisely because the British "absolute" unit of force has been made dependent on this arbitrary unit of mass and the equally

arbitrary units of time and length, that I object, not, as Mr. Barnett would have it appear, to the *unit of force*, but to its name.

Whether this name would be any more appropriate for such a unit of force as Mr. Barnett proposes, there will be time to consider when some physicist shall exhibit the unit itself. Mr. Barnett seems astonished that I do not see that by taking one particular definition of the *unit* of force, and calling it an *absolute* unit, we should thereby be put in possession of a wonderful and otherwise impossible means of recovering lost standards of mass and force, in the contingency of a sudden contraction or expansion of the earth and the simultaneous destruction of all platinum units, spring balances, &c. It may be "a mere question of sight." I am inclined to think it is; for I am free to confess that I cannot conceive of any earthly use for such units of mass and force as he proposes, unless there is some means of determining their exact numerical relations to the actual standards used in practical mechanics. But if we have the means now of determining these relations, it follows that we already have the numerical relations of our present standards to the time of vibration and length of wave of each particular kind of light, and therefore that by those relations *it would be just as easy after a grand catastrophe to reconstruct present standards of mass and force without his "absolute" unit as with it.*

It may still be a question with scientists as to what mode of restoring a lost physical standard would insure the greatest accuracy. Mr. Barnett maintains, what is not certain, that if units of time and length were made to depend on the time of vibration and length of wave of a particular kind of light they would thus be absolutely determined for all time. But even if this were granted, the difficulties in the physical construction of a standard unit of mass accurately connected with these units in the manner proposed by Mr. Barnett are by no means slight. If such a standard of mass were once made, and then lost, and if it were required to reproduce an equal mass, having nothing to start from except Mr. Barnett's definitions and his light, it would be an interesting problem to consider the probable error of the restored mass, estimating it by what we know of the probable errors hitherto made in experiments like those of Cavendish.

Mr. Barnett's observations on what he seems to regard as a scheme advocated by me for "*deriving* the unit of force," are as wide of the mark as they could well be. For, in the first place, I was not advocating one method rather than another, but simply explaining two possible distinct methods; and, in the second place, Mr. Barnett has wholly missed the point of the explanation. The first method explained was that in which units of time, space and *mass* are arbitrarily taken, and the unit of *force* then defined to be *that force which by acting for one unit of time on one unit of mass shall give it one unit of velocity.* The other method explained was that in which units of time, space and *force* are arbitrarily taken, and the unit of *mass* then connected with them by a proper definition. The arbitrary unit of force generally taken in this method is the weight of a pound. But to make the *pound force* a perfectly definite unit of force we have to specify in what place and at what time the observations for determining it are made, and we must have some means by which those who are to make actual use of the same unit can compare their standards. A practical method would be to say that our arbitrary unit or pound force shall be the force (or pressure) due to the action of gravity on a particular piece of platinum in London at a particular time; and, to have a double check on the accuracy of the observations by which this unit of force is to be registered, we may record its action both in producing the distortion of a properly constructed spring *and in producing motion.* Having then thus adopted an arbitrary and definite unit of force, and provided means of practically comparing other forces with it, a unit of *mass* can be derived from the three arbitrary units by the following definition: *The unit of mass shall be that quantity of matter which, when free to move, and when acted on for one second by a pressure (force) of one pound shall acquire a velocity of one foot per second.* This, briefly, was my explanation of one method of establishing the main units of a

system of mechanics. Let us see what my reviewer makes of this method. He says: "Prof. Skinner, assuming the usual units of time, length and mass, proposes to *derive* the unit of *force* from them." On the contrary, the method was to assume a perfectly arbitrary unit of force, to observe its action and make a record of it by various experiments on a convenient piece of platinum at a particular time, and then to *derive* a unit of *mass* by the dynamical definition just given above. What are the two steps by which this process severs the connection imposed by nature?

Without saying that this system was better than that in which the unit of force is derived by Gauss' definition, I was arguing that writers who prefer to derive the unit of mass by definition from the unit of force ought to first make their arbitrary unit of force invariable, so that there should be a definite ratio between the units of mass and of force in the two systems; and so that students could pass by simple multiplication or division from one to the other. Mr. Barnett says that although the pound is not a weight but a mass, yet the pound weight is a force, and a variable one. Some writers may frame their definitions so as to make their pound weight a variable force, but we have a plenty of others who use the term *pound* consistently as a name of an invariable unit of force. Every writer, for example, who says that a body which weighs 1,000 pounds at the equator will weigh about 1,005 pounds at the pole, assumes in this statement that the pound is an invariable unit of force. It may, and undoubtedly does, lead to more or less confusion, to employ the word pound to mean sometimes a mass and sometimes a unit of force; but since there are hundreds of writers and millions of practical men who use the word in both senses, we have to do the best we can under the circumstances. I accordingly suggested a definition of a *pound force* which should be invariable and should bear a definite ratio to the British "absolute" unit of force, being a quantity of precisely the same kind. Mr. Barnett's talk about my being blinded by the subterfuge of a spring, and of my surrender to Prof. Tait's principle of measuring force, is irrelevant. He writes as if I had argued against the propriety of ever measuring forces by the motions they can produce. I have done nothing of the kind. I explained that the *pound force*, as determined by the present intensity of gravity at London, was found to be equal to 32.1912 so-called "absolute" units; hence, when I say that forces are properly measurable in pounds I by the same statement make them also measurable in terms of the "absolute" unit. Furthermore, I explained Newton's second law of motion to be actually a rule for measuring the intensities of forces by the *changes of motion* produced by them; although this is not the only legitimate way to measure forces, and no mechanic is ever likely to confine himself to it if another way is more convenient.

Whether a properly constructed spring would not enable us to preserve a more accurate means of practically comparing forces than the resort to experiments on motion may still be a question. The "subterfuge of a spring" has indeed been suggested, even by Thomson and Tait. I quote from their Nat. Phil., Vol. I, art. 406.

"The ultimate standard of accurate chronometry must (if the human race live on the earth for a few million years) be founded on the physical properties of some body of more constant character than the earth; for instance, a carefully arranged *metallic spring*, hermetically sealed in an exhausted glass vessel. The time of vibration of such a spring would be necessarily more constant from day to day than that of the balance-spring of the best possible chronometer, disturbed as this is by the train of mechanism with which it is connected; and it would almost certainly be more constant from age to age than the time of rotation of the earth (cooling and shrinking, as it certainly is, to an extent that must be very considerable in fifty million years)."

Without expressing any opinion as to the merits of this plan I simply observe that if such a spring would answer some millions of years for an accurate chronometer, it would not be beyond all possibility to make a spring that would serve for a short time as a practical means of comparing forces.

Mr. Barnett, referring to my conclusion, drawn from experiments and dis-

cussion, that the word *force* in Newton's second law of motion means no more than *pressure* or *tension*, asks; "How are we benefited by this knowledge?" Simply by realizing clearly what words are properly synonymous with *force*. Mr. Barnett says that by this I mean to prove that force is not *the rate of doing work*. To which I reply that the most that a careful reading of my argument on this point develops is that I do not think Prof. Tait's definitions, as given in the report of his Glasgow Lecture, the only necessary and sufficient ones. I did not undertake to show either what force or tension is or what it is not. I have admitted, Vol. XVII, p. 423, and Vol. XVIII, p. 166, that I do not know in what the intimate nature of pressure or tension (force) consists. I accept it for the present as an ultimate fact of nature. But how does it help the matter to define *force* to be nothing but the name for a *rate of doing work*? If we take this as the only proper and sufficient definition of force how are we to define *work?* The general idea of work is the *exertion of force* through some definite distance. Thomson and Tait, Nat. Phil. art. 238, say that the *unit of work* is the unit *force* acting through unit of *space*. But if *force* is nothing but a *rate of doing work*, then *work* is nothing but the action of a *rate of doing work*, and we may just as well say that *force* is *force*, and *work* is *work*, and confess that we know nothing of either of them.

The points of Mr. Barnett's criticism remaining to be noticed need not occupy us long. He says incidentally that a penny letter, resting upon a table, has *work* done upon it by gravity. If so, supposing it to remain at rest for half an hour, what is the amount of work done, in foot-pounds?

Concerning one of Prof. Tait's expressions in his Glasgow Lecture on Force, I had said: "I never saw it stated elsewhere that *the horse-power done by an agent in each second is the product of the force into the average velocity of the agent*, or that *the horse-power in each second* is such a product, or even that the *horse-power* is that product." On which my reviewer says it is to be supposed that I think I see these things stated by Prof. Tait. But that does not follow. A person familiar with the function of the little word *or* would say at once that all which could properly *be supposed* is that I think I see at least *one* of these things stated by Prof. Tait; and whichever thing was stated, it seemed to me could have been much better stated, in an address which was professedly a special plea for scientific accuracy. As Mr. Barnett has kindly pointed out the term which was meant to be synonymous with horse-power, viz., *amount of work done by an agent in each second*, I will simply add that I can find in Prof. Tait's Glasgow Lecture no unit of *work* given except the foot-pound; and that a *horse-power* is not the *number of foot-pounds of work done by an agent in a second.*

Concerning the comparison of force and momentum, I had agreed fully with Prof. Tait that they are two entirely different things; but, for all that, Mr. Barnett thinks necessary to inform me that a square cannot be affirmed to be a cube. He apparently supposes that my criticism of what seemed to me a poor argument, was given with the intention of discrediting the distinction between force and momentum. On the contrary I simply suggested that better arguments might have been employed.

Again Mr. Barnett says he is unable to say why I speak of "both" propositions in Prof. Tait's sentence "momentum is the *time integral* of force, because force is the rate of change of momentum." I used the word "both" because the sentence contains, for logical purposes, and for the purposes I had in view, two propositions, Mr. Barnett to the contrary notwithstanding. My next words undoubtedly informed most of my readers that I had already presented some objections to the proposition "*force is the rate of change of momentum*;" and I went on at once to state independent objections to the proposition "*momentum is the time integral of force.*"

Mr. Barnett says that he cannot imagine what I understand by a *time integral.* He need not try. He may simply observe that although I found that the *integral* of a particular force, assumed to increase during five equal increments of time according to a certain law, would be nine pounds, I did not call this or any

other result a *time* integral, as would be supposed from my reviewer's statements.

In another place I had brought together two statements of Prof. Tait's; one being that *force is not an objective reality*, the other that *the product of a force* into the displacement of its point of application *has an objective existence*. Without admitting or denying either of these statements, I simply suggested the reconciliation of the two as a fit theme for a metaphysician; which suggestion Mr. Barnett seizes as an admission by me that *force* is merely a *rate of change*. To compare two statements made by a lecturer, is not necessarily to admit or deny the truth of either of them.

Whether or not a writer, with a rational ambition for obtaining the best possible views on questionable points of science, ever allows his zeal to carry him beyond the limits of fair discussion, must of course be left to the decision of impartial readers; but in closing I may be pardoned for saying that I fail to see my reviewer's consistency in beginning such an attack as his with a charge of excess of zeal for controversy on my part, and ending it with a sigh of regret that Prof. Tait's "zeal in slaying" has not yet called forth anything further from him.

ON THE PROTECTION FROM ATMOSPHERIC ACTION, WHICH IS IMPARTED TO METALS BY A COATING OF CERTAIN OF THEIR OWN OXIDES, RESPECTIVELY.

By JOHN PERCY, M. D., F. R. S.

Journal of the Iron and Steel Institute.

There appeared in the *Times*, of March 6th, 1877, an announcement, in glowing language, of an alleged discovery of Professor Barff, by which iron might be effectually prevented from rusting and, "however much exposed to weather, or corrosive vapors, or liquids," might be rendered "practically indestructible and everlasting." The process consists in exposing iron to the action of superheated steam, whereby it requires a tenaciously adherent coating of one of its own oxides, viz., magnetic oxide, which it is asserted protects the underlying metal not only from atmospheric oxidation, but also from that of corrosive reagents. The fact that magnetic oxide would be formed under those conditions was known to every chemist, notwithstanding the statement of the writer of the article in the *Times*, that it was discovered by Professor Barff. That iron upon the surface of which a coating of magnetic oxide has been formed, by the joint action of heat and atmospheric air, is preserved in a greater or less degree from rusting is a fact well known, I should suppose, to every member of the Institute before the announcement of Professor Barff's discovery; and, perhaps, the most striking example that can be adduced in proof of such protective action is afforded by a variety of Russian sheet iron. In a pamphlet which I published in 1871, I described the special character of this sheet iron, and communicated such information as I had been able to procure concerning its manufacture. The following is a quotation from that pamphlet:—"A particular kind of sheet iron is manufactured in Russia, which, so far as I know, has not been produced elswhere. It is remarkable for its smooth, glossy surface, which is dark metallic grey, and not bluish grey, like that of common sheet-iron. On bending it backwards and forward with the fingers, no scale is separated, as is the case with sheet iron manufactured in the ordinary way by rolling; but on folding it closely, as though it were paper, and unfolding it, small scales are detached along the line of the fold . . . . This sheet iron is in considerable demand in Russia for roofing, and in the United States, where it is largely used in the construction of stoves and for encasing locomotive engines."

Now, from the circumstance of its

being applied to the purposes just mentioned, especially roofing in such a climate as that of Russia, it may be inferred that it must be much less liable to rust than ordinary sheet iron; and of the correctness of that inference I have had personal experience. In 1846, I constructed, of this Russian sheet iron, a gas combustion furnace for organic analysis which I exhibited to the meeting of the British Association, at Southampton, in the same year. Ever since that period the furnace has been exposed to the atmosphere, sometimes to that of a laboratory, and yet it presents only here and there small spots of rust. Other specimens of similar sheet iron, which I have had in my possession for fifteen years and upwards, remain free from rust, notwithstanding that they have also been freely exposed to the atmosphere.

The metal used for the sheet iron in question is made from pig iron, either in a charcoal finery, or the puddling furnace; but according to one account, only in the former. The pig iron is produced by smelting magnetite, spathic iron ore, and red and brown hematite, with charcoal and cold blast. For a detailed account of the process of manufacture, I must refer the members of the Institute to the pamphlet which I have mentioned, but there is one operation to which I invite their attention, and which is conducted as follows:—The rolled sheets are sheared to the dimensions of 28 inches by 56 inches: and each sheared sheet is brushed all over with a mixture of birch charcoal powder and water, and then dried. The sheets so coated, with a thin layer of charcoal powder, are arranged in packets containing from 70 to 100 sheets each; and each packet is bound up in waste sheets, of which two are placed at the top and two at the bottom. A single packet at a time is re-heated, with logs of wood 7 feet long placed round it, and, for this purpose, a furnace of particular construction is employed, which will be found fully described and illustrated in the pamphlet referred to, and a copy of which I herewith transmit. It consists of a re-heating chamber above and a fire-place below, the two being separated by a floor, containing holes, through which the gaseous products of combustion from the fire-place pass into the upper chamber. The object, it is stated, of the logs of wood is to prevent as far as possible, the presence of free oxygen in the re-heating chamber. The packet is thus slowly heated for five or six hours, after which it is withdrawn and hammered. Now, during a considerable portion of this period steam would continue to be evolved from the logs, and it becomes a question, whether that steam may not be instrumental in forming a superficial coating of magnetic oxide of iron on the sheets of the packet. But it was not until I had read the account of Dr. Barff's process that this notion occurred to me. If it should prove to be well founded, then another would be added to the many remarkable instances in metallurgy of practices having been introduced, and long carried on, without even a suspicion of the scientific principles which they involve.

Assuming the correctness of what has been asserted concerning the action of a coating of magnetic oxide of iron in preserving iron from rusting, it seems extremely probable that such action is due in great measure, if not wholly, to a peculiar physical state of the oxide. One condition is also essential, namely, the perfect continuity of the coating; for I have observed that when an article which had been coated by Prof. Barff himself, and from which the oxide had been expressly removed in one or two places, was exposed to the joint action of air and water, especially salt water, rusting speedily took place at the denuded places, and proceeded with rapidity; but whether more rapidly than in the case of ordinary sheet iron, exposed to similar conditions, I cannot state, as no comparative experiments were made. This, however, is a point which will deserve particular attention.

I trust that, in submitting the foregoing remarks to the meeting of the Institute, a desire to disparage Professor Barff's application will not be imputed to me. So far from having any such desire, I have pleasure in expressing my opinion that great credit is due to the Professor, both for the originality of his proposal and for the manner in which he has experimentally investigated the subject.

The next example which I have to submit to the Institute of the protection

from atmospheric action afforded to a metal by a coating of its own oxides is copper, and it is a very striking one. For more than a century, European metallurgists have been familiar with small thin bars of cast copper, of Japanese manufacture, which present a beautiful rose-colored tint, due to an extremely thin and pertinaciously adherent film of red oxide of copper, or cuprous oxide. This tint, according to my experience, is not in the least degree affected by free exposure of the bars to the atmosphere. I have had such bars in my possession for more than thirty years, and, although they have been freely exposed to the atmosphere during the whole of that period, yet they have not undergone the least change in appearance; they remain as bright and as beautifully colored as they were when I received them. Now as every one knows, when a piece of ordinary copper is exposed to the atmosphere it speedily acquires a dark-colored tarnish. Hence the conclusion that there is some peculiarity on the surface of the Japanese copper which protects the underlying metal from atmospheric action; and that peculiarity it may be demonstrated, is the presence of a film of cuprous oxide, in a particular physical state which acts like varnish. The bars of Japanese copper are actually cast under water, the metal and the water, previously heated to a certain degree, being poured at a high temperature. I have fully described the process in a volume which I published in 1861, and I have recently obtained additional information on the subject from my friends, Messrs. Tookey & Godfrey, who have witnessed this singular process of casting in Japan. I have also succeeded in thus casting copper under water. It would be out of place, on the present occasion, to describe the process in detail. All that need be further stated is, that when copper is so cast, under suitable conditions of temperature it acquires a coating of cuprous oxides which acts in the manner described. The temperature is such that the so-called spheroidal action of water comes into play and the metal flows tranquilly under water. The superficial oxidation is probably due to the action of a film of steam which there is reason to believe surrounds the copper under these conditions: and when copper is heated to a high temperature in steam, the latter as shown by Regnault's experiments, is decomposed with the evolution of hydrogen and the formation of cuprous oxide.

The last example of the action in question, which I shall mention, is afforded by lead. In the collection of the Museum of Practical Geology, in London, is a number of very thin sheets of lead, coated with bands of varied and extremely bright colors. Although the atmosphere has had free access to these sheets for about thirty years, the colors are as intense and as bright as they were at first. The sheets were prepared at Mr. Beaumont's smelting-works, by dexterously skimming in the process of desilverizing lead by Pattinson's most original and beautiful process; and were presented to the Museum by Mr. Sopwith, at that time general manager of Mr. Beaumont's mining and smelting establishments. The colors are certainly caused by excessively thin films of oxide lead of various thickness.

[NOTE.—Colonel W. H. Paine, of the Corps of Engineers of the East River Bridge, produced by a process of his own in 1869 a surface of magnetic oxide upon steel measuring tapes, which has proved a perfect protection from further rusting and the tapes are yet in good condition.—ED.]

A COMMISSION has, it is stated, been appointed by the Belgian Government, consisting of twenty prominent civil and mining engineers, iron manufacturers, architects, and railroad officers, to enlarge the field for the consumption of iron. The report of the Minister of Public Works, in accordance with which the commission was appointed, urges the investigation particularly as likely to increase the demand for the products of the Belgian ironworks, which have long been suffering for the want of sufficient orders. The Minister mentions that in his department already experiments have been made in renewals of wooden railroad ties by an iron substructure with hopes of success, and he mentions as worthy of attention the substitution of iron for wood for frames, floor beams, cranes, scaffoldings, &c., in building; for supports, &c., in mines, &c.

MARINE ENGINE FRICTION.

From "The Engineer."

ALTHOUGH Mr. Isherwood, of the United States Navy called attention many years ago to the great loss of power which resulted from the friction of marine engines, it is only recently that much attention has been given to the subject in this country. Plenty of evidence that this loss is very considerable, and that friction entails very objectionable consequences, is however not lacking; and it is possible that marine engine builders may yet see their way to reducing both the loss of power and the trouble caused by friction by an appreciable quantity. So long as the effects of undue friction are rendered manifest only by the heating of bearings which can hardly be kept cool by an affusion of cold water, they are passed over with comparative neglect. It is to be hoped that the labors of such men as Mr. Froude, and the convincing proofs that he can supply that engine friction in all its forms represents a dead loss to the shipowner, may operate more forcibly than the complaints of the unfortunate sea-going engineer, whose whole life in the engine-room is rendered miserable by the fear that they may have a hot bearing at any moment. It has often been asked by those whose experience is confined to stationary engines, why it is that so much trouble is experienced at sea from hot bearings? The fact is that, on land, engines are worked under very different conditions from those which obtain at sea. Very few land engines work up to anything like the power developed by marine engines. If our readers will now draw on their own experience, they will find that the number of stationary engines in factories, ironworks, or mills indicating more than 500-horse power may almost be counted on the fingers. It is found better in such establishments to divide the motive power among several centres of distribution, than to concentrate it all in one place. But it is no exaggeration to say that there are thousands of marine engines indicating more than 500-horse power; and it is well known that small marine engines seldom give much trouble with hot bearings. The larger the engine, the greater the chance of heating. Mr. Froude has designed an exceedingly ingenious dynamometer for ascertaining the loss of power by engine friction; but apart from this apparatus, he has been able to get at facts of extreme interest bearing on the subject. The method he adopted he described during the discussion which took place on Mr. Holt's paper on "The Progress of Steam Shipping," read before the Institution of Civil Engineers on the 13th of last November. We can best explain the nature of this investigation by quoting Mr. Froude's own words: —"Mr. Denny, of Dumbarton, had not been content with the usual mode of trial of his ships at what is called full speed and half boiler power, or half speed, but he decided that he would get a regular progression from the highest powers he could deliver to the lowest, and correlate them with the speed of the ship. In that way a series of interesting results was obtained, and expressed in the form of a diagram, in which a base line represented units of speed, and a series of vertical ordinates erected on it the horse-powers. A curve uniting the ordinates at the top could now be drawn, and the curve thus drawn went through the zero of horse-power at the zero of speed, in virtue of the speed factor in indicated horse-power. But when the matter was separated into its constituent elements, a totally unexpected, but most instructive result, was obtained. Dividing out from the horse-power the speed factor, propulsive force was obtained, or the equivalent. It was usual to represent the work done by an engine by the product of the pressure on and the speed of the piston; but it might be described equally well—on the supposition that no friction existed—by the product of the virtual speed of the screw and the force delivered by the screw. Now, using the force factors thus deduced from Mr. Denny's experiments as ordinates, at each speed a curve was obtained in which the force ordinate refused to come to zero at the speed zero. The lowest speed was about three or four knots, and a fair

curve drawn through the force ordinates given by the succession of speeds, instead of being a curve running down to zero, was a curve that terminated on an ordinate about one-seventh of the maximum force ordinate delivered at the highest speed. That, when looked into, represented the dead friction of the engine—the force required to turn the engine round when unloaded. A variety of ships was tried in that way, and all the curves, when analyzed, yielded the same result." In other words, we have no less an authority than Mr. Froude showing that one-seventh of the power of a marine engine is wasted in friction. Of course, this does not all concern shaft bearings; but it will be admitted that, concern what it may, it represents a very serious loss. To put it in plain terms, for every 600 tons of coal which a steamship expends in propulsion, she must burn another hundred in simply working her engines; and it becomes evident that the loss thus involved may become a very serious item in the expenses of such steamers as those of a couple of thousand tons cargo capacity running to India *via* the Suez Canal, and propelled by engines indicating from 500 to 700-horse power, to say nothing of fast passenger ships, indicating three or four times as much, and making equally long voyages. Of course it is impossible to get rid of all friction, but it is quite certain that as much can probably be saved by reducing it as by jacketting cylinders, or adopting other means of economising the consumption of steam.

The question is now, can friction be reduced? It is obviously impossible to consider this problem in all its aspects within the space at our disposal. We shall deal, therefore, for the present, with one point only, namely, crank shaft friction. In the course of the discussion, to which we have already referred, Mr. Froude stated that an instance had come under his own observation in which the friction of a crank pin 22in. in diameter and 22in. long, was so great that, assuming the coefficient of friction to be one-fifteenth, "it came out, when the engine was working at its greatest speed, that work delivered on the crank pin in the shape of friction was almost equivalent to a delivery of heat at the rate at which heat is delivered to the internal surface of the fire-box of a locomotive. The heat delivered at that rate had to be radiated away or got rid of in some manner by the crank arms and connecting rod brasses, but there was a great deal of heating and trouble with the bearing." To make this statement thoroughly intelligible, let us take a somewhat similar case. The low-pressure cylinder of a compound engine is 90in. in diameter; the crank pin is 20in. in diameter and 20in. long in the connecting rod brasses. The boiler pressure is 80 lbs. on the square inch, and the net pressure on the large cylinder at the beginning of the stroke is a little over 30 lbs. absolute. This brings a load of rather over 85 tons on the crank-pin at the beginning of the stroke, or 477 lbs. per square inch of crank-pin bearing surface, assuming that surface to be equal to one-third of the whole surface of the pin. The average pressure throughout the larger portion of the stroke will not be much less than 20 lbs. To be on the safe side, let it be taken as a little over 14 lbs., equivalent to, say, 40 tons. The revolutions per minute are 50, and any point in the circumference of the crank-pin thus passes over a distance of 262ft. per minute. Taking the coefficient of friction at $\frac{1}{15}$, we have $\frac{896{,}000}{15} \times 262 = 1{,}565{,}013$ foot-pounds per minute, or over 47-horse power. But the load and pressure are not confined to a single journal, and, assuming that there are two main bearings for one crank-pin, then each of these will offer a resistance equivalent to one-half that of the crank-pin. The gross frictional resistance of the three bearings will therefore amount in round numbers to 96 indicated horse-power, and all the work thus done takes the form of heat. Now a horse-power of 33,000 lbs. raised a foot high in a minute represents, according to the latest researches, as nearly as may be, 42.63 British thermal units per minute. In order that the crank-pin may be kept cool, over 2000 units of heat must be got rid of per minute. But this heat would suffice to raise 20 gallons of water per minute from 50 deg. to 150 deg. It is not remarkable that, under such conditions, water has to be turned on bearings which cannot dissipate heat by radiation and conduction sufficiently fast. Indeed, the ex-

penditure of heat in this way is a tolerably constant quantity, and there is little reason for doubting that in most marine engines the production of heat by friction, and its expenditure by conduction and radiation, are very nearly balanced. That is to say, there is scarcely any safe margin. The slightest increase in the coefficient of friction by defective lubrication may overset the balance between the influx and discharge of heat, and thus a crank pin which is at one moment running cool may five minutes afterwards be nearly red hot.

A moment's thought will show that the way to avoid hot bearings at sea is to reduce the diameter of the journals concerned, and to augment their length. For example, if the journal which we have selected for an example were 10 inches in diameter and 40 inches long, it would have the same bearing surface as though it were 20 inches by 20 inches, but the distance passed over per minute by the surface of the crank pin would be reduced one-half, and the heat imparted to it would be reduced in the same proportion. When a fly-wheel bearing heats the engine is run more slowly until it cools down, but reducing the diameter of a bearing has precisely the same effect. Forty inches of length is an impracticable dimension for a crank pin, but the pin might be made 12 inches in diameter and 20 inches long without fear of injury as far as the brasses are concerned, because the effective surface, being 240 inches, the load per square inch would be only about 850 pounds on the square inch, and this only at each end of the stroke. But it is obvious that no such reduction in the diameter of a crank pin is admissible if it has to transmit the driving force of a second cylinder to the screw shaft. The deduction is, that in so far as concerns crank pin friction, single-cylinder engines of the American type must have a great advantage over those with two cylinders.

ON OBELISKS—THEIR PURPOSE, PROPORTIONS, MATERIAL AND POSITION.*

From "The Builder."

THE generous patriotism of Mr. Erasmus Wilson, and the skill of Mr. John Dixon, C.E., have triumphed over the half a century of England's indifference, and now the monolith of Alexandria is in the Thames only awaiting, after much discussion and difference of opinion as to its proper site, to be erected in the very centre of our metropolis as an evidence of the grand ideas of the ancient Egyptians in regard to monumental art. Considering how intimately obelisks are connected with our pursuit, I have felt that it would hardly become our Institute if such an historical fact were unnoticed in our annals, and if some attempt, however brief, were not made by us to get together the leading points connected with the general subject of obelisks, their purpose, proportions, material, and position, treated from a strictly architectural point of view, without encumbering ourselves with the questions relating to precise dates, or intricate calculations of dynasties or to hieroglyphics.

They are the most simple monuments of Egyptian architecture, and among the most interesting that antiquity has transmitted to us, from the remoteness of their origin and the doubt in which we still are as to the period when first set up. The oldest, which now remains to us, is still standing at Heliopolis, near Cairo—the On, Ramses or Beth-Shemesh of the Hebrew Scriptures. Abraham was unborn, the Pentateuch of Moses was not written, when the inhabitant of Heliopolis adored his gods in the Temple of the Sun, and read upon the obelisk, still in its place, the name of Harmachis and that of King Osirtesen, who then reigned and reared it, and to whom Mariette Bey assigns the date of 2851 years before Christ. He was a powerful

* From a paper by Professor Donaldson, read before the Royal Institute of British Architects.

Pharaoh, whom eleven royal dynasties had preceded, and who was followed by twelve more, when Alexander the Great, about 380 B.C., came to consult the oracle of Ammon, and to found at Alexandria, the capital of his future Egyptian empire. They are supposed to have been principally dedicated to the sun-god Horus, of whom the hawk was a symbol, on account of the elevation to which this bird extended his flight, and of the faculty, which the ancients considered it to have, of looking at the sun with a steady gaze.

Obelisks have been, from the earliest periods of antiquity, regarded as remarkable monuments of the skill and perseverence of remote ages. They must ever be considered as valuable records of the ancient history of the Egyptians and of the skill of those periods; monumental evidences of their sovereigns and of their warlike exploits. Extracted with vast labor from their quarries as monoliths, conveyed six or seven hundred miles down the Nile, and erected with difficulty in front of their temples, they are emblems of the perseverence and love of glory of the Egyptians or their rulers. Overthrown by earthquakes or the violence of conquerors, buried in the sands, or encumbered by the enormous blocks of stone piled up to great height, the city of Thebes, even in its dilapidated state at the present day, is the marvel of the traveler for the extent and dimensions of its ruins. The ancient city, divided in its middle by the Nile, as London is by the Thames, presents two gigantic towns with remains of immense temples, which in all their accompaniments and parts are colossal, whether in the dromoi or avenues leading up to their entrance portals, their statues, their courts, and colonnades, in the hypostyle halls, and last, though not least, as objects of wonder, in their stupendous obelisks. These were lofty pillars of granite set up by the kings in front of their temples, to commemorate their victories and record their various names and titles. I am not aware that they have as yet been found in front of tombs, as suggested by Mr. Basil Henry Cooper, in his learned paper recently read before the Society of Arts. They were monoliths consisting of a square shaft gradually diminishing towards its summit up to about nine diameters high, where the faces suddenly receded up to a point, their upper portion being called a pyramidion, from the similarity of its general form to that of a pyramid, though much more rapidly sloping. I have said receding up to a point, but the fact is, that there is authority for assuming that sometimes the pyramidion had a seated figure on its top.

The Egyptians set great value upon the size of their monoliths, and if a large block were extracted from a quarry not quite corresponding in all its sides, whether as to size or form, they would without scruple use it for their immediate purpose, or shape it as near as possible to the object they had in view, without diminishing its size. The consequence is that many of their obelisks, pedestals, and sarcophagi even, where one would have supposed the most scrupulous attention to uniformity should have existed, are irregular in shape. In like manner some of the huge blocks intended for obelisks came out of the quarries mis-shapen at the smaller end, and to remedy this defect they covered it with a metal capping of the required shape rather than reduce its length by cutting off the rugged portion.

The summit of the Parisian obelisk was irregular in shape, and left quite rough. There was at the bottom of the pyramidion a channel and fillet, then a surface setting back, and the granite presenting an uneven face. It was in the same state previously to its being lowered by the French. There must have been something to cover this unsightly appearance. Our obelisk has an inscription, translated by M. Chabas from the transcript of Burton's "Excerpta Hieroglyphica," pl. 51. In it is the following line:

"He erected two very great obelisks capped with gold."

Mariette Bey mentions that round the lowest part of the obelisk of Hatasou runs an inscription in horizontal lines covering the whole of its four sides, which states that the summit of the obelisk was covered over with pure gold, taken from the chiefs of the nation; and he observes that, unless this expression simply implies an apex overlaid with a casing of gilded copper, as the top of the obelisk must have been, this inscription possibly refers to the sphere of gold (?)

which is represented on certain bas-reliefs at Sakkarah. He further says: "The obelisk was no doubt gilded from top to bottom." In examining closely, one may notice that the hieroglyphs were carefully polished, and, moreover, that the plain surface of the monument was left comparatively rugged, from which it may be inferred that it had been covered with a coating of white stucco, as so many Egyptian monuments were, which alone received this costly embellishment of gilding, the hieroglyphs themselves retaining the original color and actual surface of granite. Dr. Birch mentions that the tombs in the Libyan range behind Gournah and El-Assasif "are full of scenes of the reign of Thothmes. Two great obelisks of 188 cubits high, with gilded tops, are recorded in these sepulchres." Mariette Bey also says that, "the inscription further states that the two granite obelisks of Heliopolis were actually completed and erected in seven months from the very beginning, when first extracted from the quarry in the mountain." This use of bronze caps seems to justify the practice in modern times, as the ancient Romans possibly adopted in certain cases the same practice; and this has been handed down traditionally to our period.

When the pyramidion was perfect in its shape, and required no artificial capping, it was sculptured in sunk relief, with a representation, as on the Alnwick obelisk, of the god to whom the monument was dedicated, before whom was the king kneeling and presenting his offering, or by a group consisting principally of a sphinx on a pedestal in front of a deity seated on a throne. A very fine example of the apex of an obelisk, at Karnak, is to be seen in the full-sized cast of one side of a pyramidion, on the landing at the top of the staircase leading to the Egyptian Room, in the upper gallery of the British Museum. Imposing from its size and execution, it shows the bold depth of the hieroglyphs and rounded surface of the sunk character, polished, as Mr. Erasmus Wilson suggests, like the delicate carving of a gem.

The next division of our subject relates to the shaft of the obelisk. The sides were not always equal in their width, varying a few inches. In the exceptional instance of the obelisk of Biggeg or Crocodilopolis in the Fayoum, called by Mr. W. R. Cooper, in his able book on this subject, an obeliscoid monolith, the faces are 6 feet 9 inches broad, the sides only 4 feet thick. Our London obelisk is at the base 7 feet 10.3 inches by 7 feet 8 inches; at the summit, 5 feet 1.3 inches by 4 feet 10.25 inches,—an inappreciable difference. The four sides or faces of obelisks were usually square, but occasionally they are convex; a fact proving the nice perception for effect, which prevailed in the minds of the ancient Egyptians, as thus the light was much softer upon the surface, the shade less crude, and the angles less cutting. Whether there is in any an entasis in the upright line has not yet been precisely ascertained, but perhaps this fact may now be set at rest in repect to our Alexandrian obelisk. Usually obelisks had one, two, or three vertical lines of hieroglyphs. Originally it may be assumed that only one central series was contemplated by the original Pharaoh; but it appears that his son, successor, or successors, added a line on each side; and it is remarkable that earlier hieroglyphs were much deeper cut than the more recent ones. Occasionally some of the hieroglyphs have been altered or erased, more or less deeply cut, and the names of other gods or Pharaohs have been substituted, like the inscriptions upon some of the Roman triumphal arches. I just now noticed the mention made by Mariette Bey of the faces of obelisks having been gilt, the hieroglyphs themselves retaining their original color and actual surface of granite. It is not impossible that occasionally the hollows of the hieroglyphs may have been filled in with some colored substance, in like manner as we see on the frescoes the hieroglyphs painted in different colors, like those preserved in the Egyptian Hall of the British Museum. These inscriptions are generally trivial and meaningless, recording little more than the names and patronymics of the king, his relationship to the gods, and list of his virtues, and of the people he may have subdued in battle; sometimes with maxims and blessings of the gods.

We have now to consider the dies, pedestals, and steps upon which the obelisks were anciently raised. On this

subject we have very little reliable information, for the bottom portions of those now left standing in Egypt are encumbered and surrounded by huge fallen blocks of stone, preventing their full size from being ascertained; and on those transported to Constantinople, or Rome, or elsewhere, from their original sites, no reliance can be placed. Our late friend, Mr. Joseph Bonomi, may be considered a great veteran authority on the subject of obelisks, as he made it a special object of study when in Egypt and in Rome; and there is a very complete enumeration and analysis of existing monoliths by him in vol. i. of the Second Series of the Transactions of the Royal Society of Literature, 1843, and a description of the Alnwick Obelisk. By his liberality the Institute possesses two fine models of obelisks at Karnac and Luxor. In a private letter to myself he says that he had seen the upper part of the block of granite on which that of Karnak stands—"It is cubical; on two sides the surface is vertical, on the two other sides the surface inclines very much, but the exact angle I do not know, nor do I know how high the block is, for the lower part is encumbered by large masses of stone." The model was made for the late Duke of Northumberland (Algernon Percy). This divergence of the faces of the die is a remarkable confirmation of my previous remark as to the irregularities existing in large blocks of granite, from the desire of the Egyptians to retain, as far as possible, the cubical mass entire. Mr. Bonomi concludes his note by stating that he had measured and drawn the base of the obelisk at Luxor; that it was composed of several pieces of granite, and on the north and south sides had four statues of monkeys cut out of two or three blocks of granite in *alto relievo*. On the east and west sides are sculptured in Egyptian *cavo relievo* (hieroglyphs) figures of Nilus bringing in the productions of the country. This extraordinary mode of embellishing the pedestals of obelisks seems almost incredible, were it not for this instance, which is illustrated and detailed by M. Le Bas, the engineer, who transported the Luxor obelisk to Paris, where, however, the original pedestal forms no part of the present composition in the Place de la Concorde. This obelisk, as described by M. Le Bas, deserves our special notice, on account of its individual peculiarities.

Ramses II., whose reign began 1388 B.C., extracted the monoliths from the quarries of Syene, and transported them to Thebes, and partly incised the hieroglyphs of the middle column. His brother and successor, Sesostris, whose reign began 1328 B.C., completed the inscriptions. It thus appears that the hieroglyphs were executed before the erection; for Ramses II. set up the obelisks 1388 B.C., and had his name engraved on the base as an historical record. The total height of the shaft is 75 feet, at its base 8 feet wide, with an average of 5 feet in width. In its elevation the opposite faces in their height have a different curvature,—on the one side being convex and the other concave, to the extent of about a couple of inches, an imperceptible difference from a straight line; but it is remarkable that the two obelisks coincide in this detail. I imagine that the first block must have been irregularly marked out and worked, and the second one compelled to follow the faulty line in the quarry. The pedestal of each obelisk is composed of two distinct parts, its base and its die. The base or plinth resting on the pavement consists of three horizontal blocks of three courses of sandstone; the central die is a granite monolith, supporting the weight of the obelisk, and has on two of its sides four projecting monkeys in high relief, the other sides being plain, with the exception of incised hieroglyphs. One side of the die with four of the monkey figures was a slab-facing of the die, and it consequently did not contribute to its solidity. The entire monument was erected on a gray stone paving, and was sunk into the paving-blocks a few inches. Such is the very remarkable construction and decoration of these, I presume, very exceptional instances. As to the pedestals of the obelisks, we may infer that in other cases the monoliths rested on one or more steps, and that they did not rise at once without any superstructure or plinth from the level of the pavement. Sometimes bronze balls or other supports at the angles raised the monolith a few inches above the slab or block beneath. Mr. Dixon discovered an inscription engraved in

Greek and Latin on the bronze crabs supporting the standing obelisk of Alexandria, having the words "Anno VIII. Cæsaris, Barbarus Præfectus Ægypti posuit; Architectore Pontio" (see Erasmus Wilson's "Cleopatra's Needle," p. 11). This explains the reason why some of the obelisks at Rome have the like angular supports.

The erections on the banks of the Nile were constructed of the sand and limestones extracted from the quarries near. The pink granite was only used for the obelisks, statues, sarcophagi, casings of the pyramids, sanctuaries in temples, and linings of some special tombs, and for other precious or sacred purposes. The position of the quarries of Syene must have been of the utmost importance in facilitating the application of that fine material. Situated below the rapids,—or, as they are generally called, the cataracts,—when once the masses were extracted from their beds, no obstruction presented itself in their course down the river to their destination, whether to Memphis, Heliopolis, or the Delta. Mr. W. R. Cooper states that twenty-seven of the forty-two obelisks now known were from Syene, and they are doubtless the largest. An unextracted block still remains at Syene, 95 feet long by a diameter of 11 feet, with the quarrymen's marks upon it. Sir Gardner Wilkinson mentions that the final operation of extraction, when three sides of a mass had been worked round, was by cutting a groove or channel about 2 inches in depth, and kindling a fire along its whole length. When the stone was intensely heated, cold water was poured into the groove, and the block detached itself with a clear fracture. Wedges of wood were also inserted, saturated with water, then exposed to heat, and the expansion rent the mass asunder. Thus detached, it was drawn down to the river, where it was encased, or upon a gallery or raft floated down the Nile to near the spot where it was ultimately to be set up. From the river-bank it was hauled to the propylæ in front of which it was to be erected. We have no hieroglyphs or paintings on the walls of the pyla or tombs showing how the obelisks were raised and placed in their final position. That the erection of the monolith on its pedestal was a most critical operation is sufficiently obvious, and its difficulty is illustrated by an anecdote related by Pliny:—Ramses erected an obelisk 140 cubits high and of prodigious thickness. It is said 120,000 men were employed on the work. To insure the safety of the operation by the extremest skill of the architect, he had his own son fastened to the summit while it was raised. On a small illustration before you there is represented a mural painting in a hypogee, or underground tomb, at Gournah, with three men polishing a column of no great size; but that may be conventional. The column rests on blocks; the polishers are astride, or seated on the column, with rubbers rubbing the surface. Another, from the same tomb, shows a colossal upright figure surrounded by scaffold-poles; five artisans are chiseling, rubbing, and polishing the surface. Another small illustration represents a mason carving a many-colored sphinx; he is chiseling the paw of the animal; he has a wooden mallet in his right hand, and in his left a steel chisel, unmistakably indicated by the deep blue color of the tool. We know not whether emery or what other powder was used by the polisher.

I have not yet alluded to the masons' and carvers' operations of cutting the hard materials used in their obelisks, statues, sarcophagi, &c., such as the pink and black granite, black marble, basalt, &c. Hardly any iron tools have been preserved among the relics of the tombs. With what materials did the ancient Egyptians carve with such refined delicacy and exquisite sharpness the mouth, eyes, and other features of their statues, or what Mr. Erasmus Wilson calls the gem-like surfaces of the *in cavo relievo* of the hieroglyphs? I do not know that we are possessed of any process by which brass may be sufficiently hardened for the purpose, and we have not specimens enough which have survived the oxidation of the iron to satisfy us on the point as to that material. Could they prepare and soften the surface by some chemical application on the harder elements of their hard stones? No one as yet has been able to inform us; but the secret mystery of the execution of the Egyptian sculpture still evokes our wonder and admiration of their skill. Our own granite merchants

have achieved wonders, by means of steam machinery, in working out by rotary motion the shafts and bases and caps of certain columns and circular pedestals; but the refined sharpness of the lips, eyebrows, and other delicate features of the Egyptian heads, as they appear even upon the lids of the sarcophagi or the busts in the British Museum, has yet to be attained.

I have before observed that the Egyptians were less careful as regards any fixed proportions of their monoliths, but were more anxious to use up the blocks as they came from the quarry, whether as to the height or uniformity of shape. The sides of an obelisk rarely corresponded exactly to the breadth of its face, or the height of the shaft to any fixed relation with the width at the base; and there is a like disregard in the height of the pyramidion, which, however, was high-peaked, and never stunted. Nevertheless, we may generally assume that the shaft varied from eight to nine diameters high up to the pyramidion, which was from sixty to seventy-five hundreds of the breadth at the base. Too few of the pedestals, plinths, or steps have been ascertained or measured to afford any general law of proportion, whether as to their breadth or height.

The positions of obelisks were before the gigantic pylons, which formed the entrance gateways to the forecourts of their temples, and they were, I think, without exception, always in pairs. At Karnak the situation of the two lofty ones erected by Queen Hatasou (one of which still stands, and is, according to Mariette Bey, 108 feet 6 inches high, the loftiest one known) was between two lofty pylons only 40 feet or 50 feet apart! Those in front of the outer pylon are not so distant in advance of it. Consequently the Egyptians disregarded the immediate proximity of a lofty wall backing them up, and none are known situated in wide open spaces. I have grouped together in a drawing the various objects which occupied the approaches to the temples and formed an assemblage that was calculated to impress with awe the dignity of the fane of their god. The sacred way led up from the river, flanked on each side with variously headed sphinxes. At Karnak the dromos is one mile and one third long, with a line of sphinxes on each side. Approaching nearer, the worshipper finds two obelisks on the right and left, not necessarily of the same height. At Luxor one is 7 feet or 8 feet higher than the other, and to diminish the appearance of disparity in size, the shorter one is raised on a lofty pedestal and brought some feet in advance of its companion. Attached to the face of the pylon are six sedent gigantic statues of kings, majestic as to size, and seated in the hieratic posture. Lofty colored poles, similar to the standards at Venice, are inserted in sinkings chased into the walls, surmounted with the expanded banners of the kings or heraldic bearings of the temple floating in the wind. The pylon itself, perhaps 200 feet wide and 100 feet high, forms the back-ground of the whole, crowned by its cavetto cornice, and its surface covered with colored sculptures of the victorious Ramses, in his chariot, with upraised arm slaying his enemies, trampling them under his horses' hoofs, and also dispersing them in flight,—a grand scene of one of the dramas in the reign of a victorious monarch. In the center of the structure is the portal, 56 feet high, and through it the sacred or triumphal procession in all its gorgeous majesty to within the sacred precincts, there to observe the ritual ceremonials of the mysterious Egyptian cult of one or more of their eight great divinities or animal gods.

Having thus given a slight sketch of the architectural magnificence of the Egyptians, allow me to offer a tribute of respect to a brother architect: his name, as given by Mariette Bey, is inscribed on the Temple of Edfou. It was Ei-em-hotep Oer-si-Phtah Imouthes, the great son of Phtah, the only one yet discovered on the monuments of Egypt. I am afraid we are too late for its insertion in the colossal Architectural Dictionary of our time, unless it finds its way into an appendix.

The chronology of the Bible, as assumed by some learned men, gives the age of the world before the Christian Æra as 4004 years. Mariette Bey (p. 22) *under reservation*, founding the calculations upon dates afforded by inscriptions upon tombs, temples, obelisks, and other monuments, gives the date of

the Egyption empire alone and its dynasties as 5004. Bunsen assumes a still remoter period, and my friend Lesueur, our Honorary and Corresponding Member, in his "Chronologie des Rois d'Egypte," commences with 20,000, which latter is to be considered as an imaginary datum from which to start in computing the history of the world. But adopting Mariette Bey's comparatively moderate number of 5004 for the beginning of the Thinite dynasty, as the historic date of the commencement of Egypt's national existence, it fills one with wonder when we consider how many gaps occur in the continuous rule of Egypt's autonomy. How could the very existence of her nationality and arts be maintained, even with periods of more or less purity, when we know that for about 1,200 years, or nearly one-fourth of her existence, she was at various times ruled and overrun by the hykshos or shepherds, the Ethiopians and the Persians, under Cambyses, Darius, and Xerxes? At last she was conquered and ruled for 332 of those years by the Greeks and Romans—from the time of Alexander and his successors to that of the Romans. Could any other people under such crushing circumstances have maintained their identity on their own native soil?

I cannot but think that the arrival and erection of the Alexandrian obelisk among us may produce very notable results in regard to our knowledge of ancient Egyptian history, connected as it is with our Bible. The old Greeks and Romans, the classics of our boyhood, have had their annals duly chronicled and reduced to elaborate histories by the learned. These, it is true, have been turned upside down by recent erudite inquiries, substituting a different and new chronology, and an assumed rational statement of facts. Egypt till very recently had no consecutive accepted history in our language, that I know of, until our learned Dr. Birch, of the British Museum,—a name honored and esteemed by all Egyptologists, whether British or foreign,—compiled for the Christian Knowledge Society his summary of the ancient history of Egypt from the monuments, putting together with vast knowledge and most critical acumen an admirable history. There cannot be a doubt that our countrymen, as they pass by our obelisk, will have their curiosity excited by the sight of hieroglyphs which may have been seen and read by the Jews in the time of Moses, or when our Saviour was taken by his parents to Egypt as a place of refuge from Herod's rage. They will seek in Dr. Birch's book the solution of the mysteries revealed in those enigmatical sculptures, and the history of that ancient people.

STEEL PLATES.

From "Engineering."

THE most accurate knowledge of the ductility and other mechanical properties of a plate can be gained by testing to destruction a strip cut from it, and this is the only method to use when we require to compare the ductility and tenacity of two or more samples with any degree of exactness. It is almost needless to say, however, that the expense of carrying out this method, with anything like the accuracy necessary to be of real service, must prevent its being adopted by all but a very few boilermakers and shipbuilders. Fortunately, however, in order to enable the user to satisfy himself of the suitability of a steel plate for any purpose for which he may require it a simpler and much less costly test is in most cases sufficient. This is what is well known as the "temper test," and consists of heating the strip of plate to a bright red and plunging it into cold water and then bending it cold. The range and suddenness of the change of temperature in cooling and the degree of consequent bending the plate will serve to indicate its quality with respect to ductility and soundness. The Admiralty temper test for steel plates is as follows; "Strips cut lengthwise of

the plate, 1½ inches wide, heated uniformly to a low cherry-red and cooled in water of 82 deg. Fahr., must stand bending in a press to a curve of which the inner radius is one and a half times the thickness of the plates tested." Lloyd's Register temper test for ship and boiler plates is practically the same as this.

We may here remark that, however valuable this temper test may be and in our opinion actually is, it is by no means an absolutely accurate test, since by skillful manipulation and allowing plenty of time for the operation, one smith can make a strip pass a given test where another will fail to do so. When the bending is done by hammering in the ordinary way, the degree to which any given plate may be made to fold back upon itself depends greatly upon its temperature and upon the direction, position, and intensity of the blows on its surface by which the bending is effected.

When a steel plate is tested for its tenacity the tensile test is made in order to ascertain whether the tenacity is not over a certain limit, rather than that it is not under this limit, and in order to ascertain the amount of elongation, the object being to determine whether the ductility is sufficient to insure absence of liability to harden locally by tempering, shearing, punching, and smithing, and sufficient not to allow cracks to spread quickly and without warning, a drawback possessed by steel and a consequence of its homogeneity. The temper test is certainly a more direct method than the tensile test of ascertaining the suitability of the material for smithing and bearing sudden cooling, while it is equally as good for judging of the other qualities, where an exact comparison is not required. It is not surprising then that the makers of steel plates use this simple temper test largely. In fact they are understood to apply it to every plate that is rolled at the present time, so that the quality of all steel plates is now pretty well insured. How long they will continue to do so it is impossible to say, but when they become more certain of the quality of the material, it is probable that the giving up of the testing of every plate will be one of the first steps towards reducing the cost when competition is keener than at present, and leads to a lowering of prices. The accumulation of test specimens must be already very large at some of the manufacturers, and it can hardly be expected that makers will long continue to mark the bent test shearings with the same number as the plates from which they are cut, and preserve them for the purpose of comparison in the event of the plates turning out brittle, as is suggested in Lloyd's Committee's report on steel for shipbuilding.

We have dwelt at some length on the value of this temper test, in consequence of hearing not long ago, at a meeting of engineers and shipbuilders, a learned professor, whose name is well known amongst naval architects, ask in an elated manner what is the value of a hot test for ship plates, for of all places in the world a ship's bottom is the least likely ever to get red hot. Had this remark come from a less enlightened source and not been received with evident satisfaction by a number of engineers and shipbuilders, it would have appeared unnecessary to say that the test was designed to prove the suitability of the plates for the treatment they received previous, as well as subsequent, to their immersion when riveted in their place.

It is well known that iron plates of any given quality are injured by punching to a greater degree as they increase in thickness. There is unfortunately a lack of experiments to show the relation between the amount of injury and the thickness of the plate. Ductile steel plates are affected in a somewhat similar manner. The thicker the plate the greater the loss of strength due to punching, and a series of experiments to determine these amounts for different thicknesses is very much wanted. With steel plates of even 26 tons tenacity and unannealed after punching, the damage as regards extension stress done by punching compared with drilling increases rapidly with the thickness of the plate and the hardness of the material. There is, however, this difference between punched steel and iron plates, that the tensile strength and ductility of the former can to a very great extent be restored by annealing, whilst the same process has comparatively little effect in restoring the strength lost in punching

iron plates. The loss of strength in a plate ¼ inch thick, punched and unannealed, may be two per cent., in a ½ inch plate 15 per cent., and in a 1 inch plate over 30 per cent., the solid plates of the different thicknesses having the same tenacity and ductility. By annealing these plates after punching these losses may be reduced to from 2 to 5 per cent. in the thicker plates. With a harder steel, say of 32 tons tenacity, the damage in ¼ inch plates unannealed would be almost 5 per cent., in ½ inch plates 20 per cent., and in one inch plates 40 per cent. By annealing the loss may be reduced to what we have given for the softer plates. It is thus seen, as regards the injury done by punching that when the plates are annealed the stronger plates may not suffer more than those of inferior tenacity and greater ductility.

The damage sustained by the plate in punching increases not only with the thickness of plate but also with the increase of ratio of thickness of plates to diameter of punch. In practice this ratio increases rapidly with the increase of thickness of plate, and this is mainly the reason that thick plates suffer so much more than thin ones. By making the die large in proportion to the diameter of punch and by keeping the point of the punch rather concave than convex and the punch and die in good order, the damaging effect of the punching can be reduced to a minimum for any given ratio of thickness of plate to diameter of punch. The American spiral-faced punch, which has lately been introduced into this country, is also stated to injure steel plates materially less than ordinary punches and experiments lately made at Crewe by Mr. Webb appear to prove this. If, however, it be required to save more of the strength of thick plates of steel than many are content to save in the case of iron plates, the steel plates must be either drilled or annealed after punching.

Since the endavour to obtain a low tenacity in steel plates, which we have advocated, is partly with a view to insure sufficient ductility to enable them to be smithed and punched without the necessity of subsequent annealing, and since there is a limit to the thickness of plate that can be punched for ordinary sized rivets without the plate requiring annealing, it is evident that our attempts to obtain such a ductility as will render annealing after punching unnecessary should be limited to a certain thickness of plate. What this limit of thickness it cannot at present be decided, but it will probably be $\frac{7}{16}$ inch and possibly ½ inch. This thickness includes nearly all plates for ordinary boiler and shipbuilding work, but does not extend to tube-plates and the shell plates of marine boilers.

If a low tenacity were required in plates to enable them to be punched for boiler-making only, we might be inclined to say let all plates for boiler making be drilled and a higher degree of tenacity be maintained, but as the low tenacity is required to insure ductility, which is affected by other processes than punching, and as the expense of drilling would tend to retard the general adoption of steel plates for shipbuilding and girder work it is advisable to insist upon obtaining the lowest tenacity compatible with uniformity and soundness of material as long as a low tenacity can be taken as an indication of a high degree of ductility.

Steel subject to stresses of varying intensity shocks, or vibration, is liable in time to lose its granular structure and to become crystalline and consequently brittle, pretty much in the same manner, although perhaps not to the same degree, that iron becomes brittle under similar circumstances. It is extremely probable that the tendency to become brittle decreases as the amount of ductility possessed by the material is increased in the first instance, and although there are not yet sufficient results gathered from experience to decide this question one way or the other, yet the presumption is so strong that the tendency to become brittle is inversely proportionate to the amount of ductility, that it appears justifiable to adduce this as a further argument in favor of attaining the greatest amount of ductility practicable.

There are very few purposes for which steel plates are used that ductility in itself is not a positive advantage. For all ship plates, for boiler shells furnace tubes, and tube plates, ductility and non-liability to temper are all im-

portant. It is perhaps only when used for flat surfaces, strengthened with screwed stays, and especially those simply rivetted over at the ends and not provided with nuts, such as most locomotive firebox plates and the flat plates in many combustion chambers and back ends of marine boilers, that the ductility may be regarded as a source of weakness, and for the following reason. The tendency of a flat plate to bulge under pressure and the amount of bulging that takes place are proportionate to the ductility of the material. As the resistance of a flat surface strengthened by screw stays without nuts depends greatly upon the hold of the threads, and as this hold is loosened by the bulging, it follows that a material like very soft steel may be less able to resist a given static pressure than an inferior iron plate that has both less ductility and less ultimate tenacity or a lower limit of elasticity. The resistance of a boiler plate to bulging, so far as its practical value is concerned is to be measured by its stiffness when stayed, rather than by its ultimate tenacity. Of two plates of a given thickness and stayed in a similar manner, that having the greater tenacity and ductility will no doubt bear at the apex of the bulging a greater bursting pressure, but for all practical purposes it may be the weaker plate of the two, and require additional stiffness by having the stays pitched closer.

The most eminent authorities on the strength of materials in treating of the strength of flat stayed plates, regard the plate between the stays as a beam, and consequently consider that its strength varies as the square of the thickness, and assume that this rule holds good alike for cast iron, wrought iron, steel and copper, by merely altering the coefficient of strength for the different materials. This rule of the strength varying as the square of the thickness can, however, only be appreciable within a certain limit of the ratio of the span to the thickness and this limit becomes less as the ductility of the material increases. The limit has not yet been decided either by experiment or theoretically for different materials, but the rule probably holds good for steel and iron plates where the distance between the stays does not exceed twenty-four times the thickness of plate. Any reduction of thickness in virtue of the greater tenacity of steel plates must be attempted with great caution in substituting soft steel for iron plates in flat-stayed surfaces. For instance, if we assume the tenacity of the steel and iron to be respectively 28 and 21 tons a $\frac{3}{8}$ inch steel plate will be equally as strong as a $\frac{1}{2}$ inch iron plate in tension. This is equivalent to a reduction of 25 per cent. in thickness, but for a flat surface a reduction of only about 13 per cent. can be allowed in the thickness of a steel plate, in order to preserve an ultimate strength equal to that of the iron plate, so that $\frac{1}{2}$ inch iron cannot be replaced by anything less than $\frac{7}{16}$ inch brae in steel. As the more ductile steel will commence to bulge before the iron plate, and sooner take a permanent set, with the above relative dimensions, it is questionable whether even this small reduction of thickness can be allowed.

Then when we come to the question of durability, if we assume the steel to corrode as fast as the iron plates, it is certain that we cannot allow even the above slight reduction in thickness if we require the steel to last as long as the iron, assuming the plates to be allowed to waste till they each have the same proportion of strength to that they originally possessed. By reducing the pitch of the stays, in order to obtain equal strength with a thinner plate, we add to both the weight and expense, and possibly increase both till the advantages of using a thinner plate vanish altogether, save where the reduction of thickness is required to facilitate the transmission of heat and prevent overheating at the joints. For locomotive firebox and marine boiler combustion chamber plates, no greater stiffness in the material itself at the expense of ductility can be recommended for the purpose of allowing a lighter plate to be used, since the greatest amount of ductility is required to prevent cracking at the stay holes and between the stays. No further evidence on this point is necessary than the fact that costly thick copper plates are still considered in this country the best material for locomotive fireboxes, notwithstanding the numerous

attempts to use thinner plates of steel and iron instead.

It appears to us that although Lloyd's Committee in their report on steel for boiler-making, allow twelve per cent. diminution of thickness when steel plates are used for flat-stayed surfaces subject to a bulging pressure, the nature and tenacity of the material itself scarcely justifies even this small reduction when the steel is very soft. We do not mean to say, however, that it is imprudent to allow this reduction, any more than it would be imprudent to allow it in a great number of cases for iron plates. The difference in strength for all practical purposes between good and indifferent workmanship often amounts to over twelve per cent. in flat surfaces of the same thickness and pitch of stays.

DECIMAL AND OTHER ARITHMETICAL NOTATIONS.

By FREDERICK BROOKS.

A Paper read before the Boston Society of Civil Engineers, April 17, 1878.

The magnificent New Palace of Westminster, in which are the British Houses of Parliament, may be regarded as a monument erected in honor of our arithmetic; for it was built to replace the old Houses destroyed in 1834 by a conflagration which was kindled by the burning of the notched sticks, or tallies, formerly used in keeping accounts. From before the Norman conquest down to 1782 this barbarous practice was maintained in the British Exchequer, similar to our treasury; and the tallies of seven centuries made a considerable wood-pile. The English found this method of keeping the national accounts such a perfect success that, after the union with Scotland in 1707, they actually sent a lot of hazel rods to Edinburgh for the officers there; but the Scotchmen, unable to appreciate their convenience, put them aside as useless lumber, and persisted in keeping their accounts in writing. The English, to be sure, had also some records in writing; they were kept in Latin, and numbers were expressed by the Roman numerals, I for one, V for five, X for ten, L for fifty, and so forth. Lord Granville was afraid that if this ridiculous bookkeeping should once be abandoned nobody could understand the ancient records. So blindly are our British brethren attached to old customs that it was not until 1831 that the Committee on Public Accounts ordered the immediate abolition of the mediæval system, and the adoption of the English language and the Arabic figures, so called. The old tallies were ordered to be burnt. In the execution of this order, in the stoves used for heating the House of Lords, the building was set on fire and both Houses of Parliament were consumed.

Into the other parts of Europe, outside of the British Exchequer, decimal arithmetic was introduced toward the close of the Middle Ages. It is supposed to have originated in India, but we received it at the hands of the Arabians and Moors. The grand peculiarity of it is that the value of each figure depends upon its position, and an additional character is devised, namely—the zero, to alter the position and consequently the significance of the other numerals by occupying space without itself denoting any number. Thus, moving a figure one place to the left increases its value ten times; two places, one hundred times; and so on in geometrical progression. The essential merit of the invention consists in this multiplication in a certain ratio; whether the ratio adopted as the base of the system be ten or some other number is a matter of secondary importance.

There would be some remarkable advantages in the use of two instead of ten. With such a binary arithmetic if we represent one by a full line and zero by a broken line we shall begin to count as follows:

1 one,
1 : two,
1 1 three, or two plus one,
1 : : four, or twice two,
1 : 1 five,
1 1 : six,
1 1 1 seven,
1 : : : eight,
1 : : 1 nine,
1 : 1 : ten,

and so on. In writing successively the above numbers we are adding one each time; if there is already one in the units' column, we "carry" one to the column of twos, and make a zero mark in the units' place; if there is also already one in the column of twos, we make another zero mark there, and carry one to the column of fours, &c. &c. Thus, only two different characters are required to represent all numbers. So there is no multiplication table necessary to be learned; multiplication becomes a matter of copying down figures, and requires no arbitrary memory of products; it is like multiplying decimally by 1, or 101, or any other number containing only zeros and ones. It is claimed that the binary notation affords superior facilities for investigating the properties of numbers, as we may more readily understand by examining some arithmetical series. Look at the units' column of the series of natural numbers which we began to write above; it contains ones and zeros alternately; reading down the next column we have two ones, then two zeros, then two ones, then two zeros, and so on. In the third column we have, or should have, four ones and four zeros; the next column goes by eights. As another illustration take the series of squares given below:

1	1
1 : :	4
1 : : 1	9
1 : : : :	16
1 1 : : 1	25
1 : : 1 : :	36
1 1 : : : 1	49
1 : : : : : :	64
1 : 1 : : : 1	81
1 1 : : 1 : :	100
1 1 1 1 : : 1	121

In the units' column there is alternation; the next contains zeros only; reading down the third column we have one, and three zeros, one, and three zeros, successively; the next column has a period of eight figures; by extending the table the law of repetition might be traced further. In this, the binary notation differs from the decimal merely in the frequency with which the periods return. Where the binary figures come back with every second, fourth and eighth number in the series, the decimals wait for the tenth, hundredth and thousandth. In the decimal squares above, if we begin at 25 and read the units' column either upward or downward, we find 5, 6, 9, 4, 1. Those figures and the zero which follows them are repeated in the same order throughout the series; no square can end in 2, 3, 7 or 8.

Binary notation is not recommended for ordinary purposes on account of its requiring so many figures to express even the smaller numbers, which are the most frequently used. Five places of figures will take us up to the number thirty-one; to denote thirty-two or more requires as many as six places. The same degree of accuracy which we now obtain by the use of seven places of decimals, in our Briggs logarithms for instance, would require twenty-three places of the binary notation. In adding up a column of but moderate length, for example the numbers written above, the sum of a single column is likely to be a number which occupies three places, so that after setting down one we have still two places to carry; whereas in adding ten numbers of our common decimal arithmetic, the largest amount we could possibly have in any one column would be ten 9's making 90, or one figure to set down and only one figure to carry.

The binary arithmetic is a device of the great Leibnitz, who divides with Sir Isaac Newton the honor of inventing the differential calculus. He circulated the knowledge of it somewhat freely; and a Jesuit missionary in Pekin, who learned of it, thought that in it he discovered the key to some lines suspended in all the Chinese temples, and supposed to be of great antiquity and mysterious meaning. These lines are called the Cova of Fohi, and are usually placed around the sides of an octagonal space. By putting them all parallel they ap-

pear as here shown. The interpretation suggested is that they express in binary notation, zero, one, two, three, four, five, six, seven.

I have dwelt at some length on the binary arithmetic, partly on account of its interesting and unique qualities, and partly for the sake of more easily enforcing the wide difference there is between the immutable relations of numbers and the peculiarities (we might almost say the accidents) of any particular method of writing them. For example, we say that twice nine is eighteen; and we cannot conceive it to be anything else. We can write the fact in binary arithmetic as well as in any other; and we can illustrate it to a child or a savage with whom we cannot communicate in any language, by taking eighteen pebbles or counters and arranging them in two rows with nine in each row. If, on the other hand, we set down 18, as usually written, and remark that the sum of the digits, 1 plus 8 equals 9, we are dealing with a peculiarity of the decimal method of writing, an interesting and valuable property, but one which does not exist in the binary arithmetic, and would not appear to a child playing with eighteen counters. We sometimes hear it said in a careless way, that there is a very curious thing about the number 9, namely, that in all its multiples the sum of the digits is divisible by 9; now that has nothing whatever to do with the abstract number nine; it merely results from the fact that one plus nine, which is ten, happens to be the base of the established system of numeration. We are so constantly using this system in all our numerical operations, and our thoughts of number are so completely identified with this method of representation, that it is difficult for us to separate our ideas of number from the Arabic figures, even when we have some other notation before our eyes. This is just as it should be; it is, indeed, inevitable; but it makes the suggestion of substituting some other notation for the decimal all over the world seem appalling. That would amount to providing new brains for the entire population. It requires some little time for a person with no more than the ordinary mathematical training to comprehend even what is meant by an alteration of our arithmetic. To alter our arithmetic, moreover, would require us to alter the records of the past for several centuries, or else it would put upon the shelf the accumulated knowledge of the race so far as it is expressed in numbers. It would embitter the lives of one whole generation.

But whatever may be thought of its practical application, it is at least an entertaining study to compare the merits of the different bases which have been recommended for arithmetical notation. Our present foundation is ten; not because of its advantages for civilized purposes, but simply because man has ten fingers and ten toes, and in the naked childhood of the race they constitute a portable mathematical library. Nearly every language spoken on this planet bears witness to the primitive tendency to number by tens; for words are many ages older than the present arithmetic. Taking as a single illustration our own mother tongue, eleven means *leave one*, twelve means *leave two*, that is, after disposing of ten; thirteen, fourteen, fifteen, &c., and our twenties, thirties and forties are of unmistakable significance. These names, by the way, would be so much more to alter, if the attempt were ever to be made to abandon decimal arithmetic.

Natural as it is for men to count on their fingers, that is of little importance now; and it is equally natural for men

to subdivide things by successive bisections. A favorite illustration is the practice in the stock market of quoting prices by per cent. and half, quarter and eighth of a per cent., where it would be more consistent to divide one per centum into ten parts instead of eight. In this month of April, 1878, some Boston brokers were weak enough to sell ten bonds of a thousand dollars each at a premium of four per cent. and three-eighths, a sixteenth and a thirty-second, making the total price $10446.875. One might imagine that they had been apprenticed to a carpenter in boyhood. Anything flexible like a cord or a piece of paper can be folded double, then doubled again, and again; whereas it is not so easy to put it into three or five folds.

There are valuable properties about a binary series; for instance a set of weights of the series 1, 2, 4, 8, 16, 32, &c., is that which forms the greatest range of combinations with the smallest number of pieces and the least total weight of metal. One-half is .5; one quarter, .25; one-eighth, .125; each halving requires an additional decimal place to express it. For the sake of greater convenience in writing these commonest fractions the base of arithmetical notation, instead of being ten, might better have been some number divisible by four. An odd number would be entirely out of the question. Several numbers divisible by four are given below, with the length of multiplication table required for each as a base, that is, the number of products which would have to be arbitrarily remembered. For comparison ten is also included in the list.

Base.	Number of Multiplications.	Modulus of Logarithms.	Places of figures required to express one ten-millionth.	Largest number that can be written with three figures.
4	3	0.7213	11.63	63
8	21	0.4809	7.75	511
10	36	0.4343	7.00	999
12	55	0.4024	6.49	1727
16	105	0.3607	5.81	4095
20	171	0.3338	5.38	7999

The modulus of logarithmic tables based on each of the numbers in the first column is added as a measure of the places of figures required in each arithmetic. Perhaps the next column will be more readily understood, in which is shown how many figures would be necessary to give the degree of accuracy that we now get with seven decimal places. It is computed from the third column simply by dividing by 0.4343 and multiplying by 7. The last column shows how many numbers could be written with three figures or less, being one less than the cube of the base.

A glance at the table is enough to throw out four as too small and twenty as too large. With four as a base we should write about five figures for every three figures that we write now; all the multiplication table we should need to remember would be twice two is four, twice three is six, three times three is nine; but the human mind easily soars higher than that. If twenty were our base we could get along with writing about three-quarters as many figures as we now do; but should have to learn nearly five times as much multiplication table. Eight, twelve and sixteen will bear further examination. They do not vary so very widely in the number of figures they require us to use; but the smallest number has a great advantage in the shortness of its multiplication table. Some other considerations are more favorable to the larger numbers.

To my thinking, the decisive difference between eight and sixteen on one side and twelve on the other is divisibility by three. The fraction one-third cannot be expressed by an arithmetic of eighths and sixteenths any better than by decimals; yet it is often desirable, if we may judge by the frequency with which we stumble upon $33\frac{1}{3}$ and the like in decimal computations. Three is a small number and is therefore much used. We have three kingdoms of nature, three powers of the federal government, three years as a term of office, three primary colors, and so on to an indefinite length. Sometimes also there is special reason for a threefold arrangement; everything that occupies space must have three dimensions; in counting out coins or other small articles it may be found that three at a time are handled with the greatest facility; in case of a contro-

versy between two, a third may be added to reach a decision, as when we have three games in a rubber or three members on a board of arbitration. The fact that twelve is a multiple of three I regard as the one sufficient reason for preferring twelve to eight or sixteen as a base of arithmetic; and this in spite of its requiring two and a half times as much multiplication table as eight would. It should be observed that in teaching arithmetic at school now, instead of stopping with nine times nine is eighty-one, children learn the multiplication table up to twelve times twelve; and they would learn the same extent of table still more easily, probably, if they were taught only duodecimal arithmetic instead of decimal. To appreciate this point let us examine the following duodecimal multiplication table, in which, as the simplest way to avoid confusion, the letters of the alphabet are used for the required eleven integers.

One.....	A	B	C	D	E	F	G	H	J	K	L
Two	B	D									
Three	C	F	J								
Four	D	H	AO	AD							
Five.....	E	K	AC	AH	BA						
Six.....	F	AO	AF	BO	BF	CO					
Seven	G	AB	AJ	BD	BL	CF	DA				
Eight.....	H	AD	BO	BH	CD	DO	DH	ED			
Nine	J	AF	BC	CO	CJ	DF	EC	FO	FJ		
Ten	K	AH	BF	CD	DB	EO	EK	FH	GF	HD	
Eleven..... ...	L	AK	BJ	CH	DC	EF	FE	GD	HC	JB	KA

The multiples of six (F) all end in six (F) or zero, just as now multiples of 5 end in 5 or 0. All multiples of four (D) and eight (H) end in four (D), eight (H), or zero; whereas now they may end in any even number. All multiples of three (C) and nine (J) end in three (C), six (F), nine (J) or zero; whereas now they may end in any number. Two, seven and eleven present about the same degree of convenience or inconvenience as now. Five and ten, of course, lose in the duodecimal arithmetic the simple appearance which they now present. The relations here pointed out would enable us to tell by inspection something about the divisibility of numbers, and a little study of this matter may assist us in judging just how much and how little the advantages of a duodecimal arithmetic amount to. Any number ending in zero would be divisible by two, three, four, six and twelve. If the last figure in a number were divisible by two, three, four or six, the number itself would be likewise divisible. If the last two places were divisible by eight, nine, sixteen or eighteen, the whole number would be likewise divisible. If the sum of the digits (begging pardon for the word) were divisible by eleven, the number would be divisible by eleven. We could not judge by inspection as to divisibility by five and seven; nor by ten, except that an odd number would certainly not be divisible by ten. By reading across the table diagonally we notice that the successive squares end in one (A), four (D), nine (J), four (D), one (A), zero, and so on repeating.

I base no argument on the common practice of dealing in dozens, grosses and great grosses; for it would be perfectly feasible to change the practice. When separate articles are sold by number, you can buy whatever number you please. There is no reason in the nature of things why sixteen eggs or sixteen

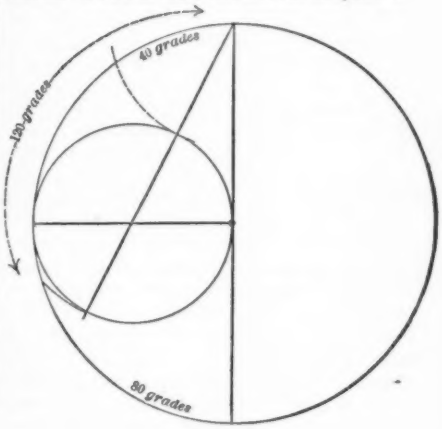
bottles of wine might not be sold instead of a dozen; no reason why ten men might not sit on a jury as well as any other number; and no reason why a washer-woman might not be paid for eight pieces as promptly as for twelve.

There is one thing to which the duodecimal arithmetic appears to be peculiarly adapted, and that is the division of the circle; nevertheless more stress is frequently laid on this point than it will bear. Let us consider the different ways of reckoning angles which are now used.

1. We have in the first place the mariner's compass which beautifully illustrates the method of continual bisection, coming down to the quarter point, which is $\frac{1}{128}$ of four right angles. I presume this is found to be very convenient.

2. In mathematical computations we often have to reckon by the length of arc in terms of radius taken as unity. This method is called for when we have expressions involving both an arc and its sine or other trigonometric function. A semi-circumference is 3.14+; a quadrant is half as much, or 1.57+; the unit being an arc as long as the radius, is rather more than five-eighths of a quadrant. It would be possible to divide up this unit decimally, and to compute trigonometric tables entered with the sub-divisions. For special purposes there would be some convenience in such an arrangement. Suppose that I am required to lay out a circular curve connecting two tangents, and to determine the true length of the curve, the radius being given or assumed. That is a common problem enough. Let me have an angular instrument graduated in the way described, and let me measure with it the angle at which the tangents intersect. I read off some decimal. The length of curve required is simply the product of that decimal multiplied by the radius; and if the radius is assumed to be a round number like 100 or 1,000, the multiplication is reduced to fixing the position of the decimal point. To establish the points of tangency and any other points on the curve involves nothing unusual in computation or field-work except the facility gained by the decimal subdivision on the instrument and in the trigonometric table. Aside from a few exceptional uses, however, the arrangement here suggested would be outrageously bad. It is not a division of the circle at all; it simply measures length of arc by a unit not commensurable with the circumference. This would be fatal to its use for the general purposes of an angular instrument; the right angle would not be marked on it, and the graduation would not come round to the point from which it started; for the mark for 6.28 would fall short of a complete circumference, and that for 6.29 would exceed it, the length being 6.2831853, &c., &c., &c. It would also be fatal to its use in most computations; our ordinary trigonometric tables are computed for one eighth part of the circle, and the same absolute values are repeated over and over again in the other parts of the circle, though the algebraic signs vary in the different quadrants. If similar tables were computed based on this incommensurable unit, the exact circumference and quadrants would not appear at all, and the values would never repeat themselves from zero to infinity.

3. We have next the centesimal division, so-called, which fully recognizes the importance of the quadrant; for it makes that the unit, and divides it into 100 grades, each grade into 100 minutes, and each minute into 100 seconds. There is a propriety in the division of the circle on a decimal scale, because, as every one knows, the chord of one-tenth of the circle bears a peculiar relation to the radius. Draw a diameter across the circle.



Tangent to this diameter at the center of the circle construct another circle with a radius one-half the first. Connect the end of the diameter with the center of the smaller circle, and produce the line so that it cuts the smaller circumference in two places. The length from the end of the diameter to one intersection is the chord of one-tenth of the original circle, or 40 grades; to the other intersection, the chord of three-tenths, or 120 grades; the difference between the two is the radius. This property has its value to a draughtsman laying out a decagon or a pentagon; but it is not much of a reason for adopting a decimal system of circular measure for general mathematical purposes. A similar remark may be made about another well-known relation, namely, that the chord of one-sixth of a circle is equal to the radius. That this is ignored by the centesimal division is the standard argument against it. An inconvenience might appear to the student beginning trigonometry; he might find that the angle whose cosine is $\frac{1}{2}$, instead of being expressed by some round number, is 66 grades, 66 minutes, 66 seconds and $\frac{6}{7}$ of a second. If in actual use there would be any serious difficulty arising from this source I have yet to learn what that difficulty is; and I have inquired of a maker of angular instruments, and of a gentleman who has had experience in astronomical observatories. It is also alleged against the centesimal division that it was abandoned after a short trial in the place where it originated. It is now used to a very limited extent; I have heard one or two things which indicate that it is receiving favorable attention in Germany; and it never was very widely adopted, though appropriate trigonometric tables have been published by Callet, by Borda, and by some others. So far as it can be said to have failed, it is not on account of any incongruity between decimal division and the properties of the circle. If, simultaneously in all civilized countries, the technical and other schools of high grade should make a business of teaching the centesimal division to the rising generation, as something which they would undoubtedly have to use in after life, no insuperable difficulty would be found in introducing it. It is comparatively a small class in the community that has to use circular measure; and that class is specially educated, and intelligent enough to appreciate the force of arguments with regard to it. That at some future time concerted action among all nations will be perfectly feasible, may be inferred from the continual increase of foreign intercourse which is now so conspicuous, and the multiplication of international exhibitions, associations and conventions, political, social, commercial and professional. The leaders of opinion will simply have to show, when the proper time comes, that it is worth while to adopt the centesimal division, and I believe it will eventually come into general use.

Centesimal grades can be reduced to the common degrees by deducting ten per cent.

4. Astronomers divide the circle into twenty-four parts called hours, each hour into sixty minutes, and each minute into sixty seconds. In this form they generally record right ascension, terrestrial longitude, and another similar angular measurement. Thus, in the American Ephemeris and Nautical Almanac the longitude of Washington Observatory, West of Greenwich, is given as 5 hours 8 minutes and $12.\frac{39}{100}$ seconds. It is also given in two other ways, one of which is .2140323, that being the equivalent decimal part of one circumference, or, as the Almanac says, of one day. This kind of angular measure is evidently borrowed from the established division of time, with which it is closely related. When it is noon at Washington Observatory, it is 5h. 8m. 12.s.39 P.M. at Greenwich. So important is it regarded in cases like this to have the division of the circle correspond with the division of time that astronomers have trigonometric tables entered directly with hours and their subdivisions, rather than go to the trouble of reducing to degrees and then working with the common trigonometric tables. The year also, being measured by the circle which the sun appears to describe upon the celestial sphere, is directly associated with circular measure. Admitting then that the measurement of time and of the circle ought to correspond, is there anything about time in itself that calls for one subdivision rather than another? Sunrise and sunset, noon and midnight, naturally divide the day into four parts. The equinoxes and

solstices naturally divide the year into four parts. The moon's phases naturally divide the lunar month into four parts. I believe that is all. As one indication that the usual division of time is not fixed by necessity, it may be observed that in various parts of the American Ephemeris and Nautical Almanac we find decimals of a year, decimals of a day, decimals of an hour and decimals of a minute. The division of the year into months may have been suggested, as the name "month" implies, by the motions of the moon; but one lunation, that is, the time from new moon to new moon, is in fact but little nearer to one-twelfth of a year than it is to one-thirteenth; and it is far enough from either. Twelve lunar months are $354\frac{4}{10}$ days nearly, or about 11 days short of a year.

5. We come finally to the common sexagesimal division, in which the sextant or one-sixth part of the circumference is divided into sixty degrees, each degree into sixty minutes, and each minute into sixty seconds. This agrees very ill with the mariner's compass, of which one point is 11° 15′, and one quarter point is 2° 48′ 45″. It is not at all adapted (as no reasonable division can be) to expressing the arc equal to radius, which is 57° 17′ 44″.8+. It marks the quadrants with the inconvenient figures, 90°, 180°, 270°, 360°, thus enabling the computer to tell, with a little effort, what quadrant any angle is in, and giving him perpetual annoyance in subtracting from those awkward numbers, to get complements and supplements. It corresponds imperfectly with the division of time; for it has 15 degrees to 1 hour, 15′ to 1m. and 15″ to 1s. It does not harmonize with the measurement of the earth's surface. If it did, it would simplify the U. S. public land surveys, which are based on meridians and parallels determined astronomically. Seamen insist on making the minute of a great circle, or "knot," their unit of distance; we call (or mis-call) this a mile, although it is about 15 per cent. greater than our statute mile. The sexagesimal division has two alleged advantages; it makes the number of degrees in the whole circumference something not very far from the number of days in the year; and it emphasizes 60°, whose chord equals the radius. The effect of this is that the angle whose sine is $\frac{1}{2}$ and the angle whose cosine is $\frac{1}{2}$ are expressed in round numbers; though the angle whose tangent is 1, and cotangent the same, is 45°, rather an odd value. Basing circular measure upon such points as these, just like dividing the year into twelve lunations, or founding arithmetic on the ten fingers, was very creditable when these things represented the highest attainments of the human mind; but in the present state of science they seem very trivial. Getting within five or six days of accuracy is now like being grossly in error. As for the importance of the angle of 60°, a surveyor might happen to measure it once in a lifetime; but is continually turning off 90° for the corners of streets and buildings and other rectangular work. In computing he uses logarithms, and finds that the functions of 60° appear as irregular as the rest.

Unfortunate though we may deem it, the fact remains that the sexagesimal division was adopted ages ago, has been in use ever since, and is now universally known; and just that fact constitutes its essential advantage. Let us examine its history. The ancient geometers and astronomers, struggling with something similar to the Roman numerals, were much troubled by the various fractions that arose in their computations, and, in order to manage them more conveniently, introduced a scheme of dividing into sixtieths. As sixty has an extraordinary variety of integral factors, all the commonest fractions can be expressed by this system. One sixth of a circumference they divided into sixty degrees, one degree into sixty primes or minutes, one minute into sixty seconds, one second into sixty trines, one trine into sixty quaternes, &c. The chord of 60°, which is the radius, they divided similarly. Their computations were chiefly confined to arcs and chords, and this really constituted a system of arithmetic. Numbers from one to fifty-nine were represented by letters and combinations of letters, but sixty was the unit of the next order or denomination, and sixty times sixty the unit of a still higher order, and so forth. Thus numbers were expressed with a facility which approaches our present notation and is

vastly superior to the Roman. It required a multiplication table extending up to 59 times 59, which must have been really a table to be consulted and not carried in the memory. Nine letters were used to represent the first nine numbers; then, instead of using the same characters over again for the tens as we do, they took six more letters for ten, twenty, thirty, forty, fifty and sixty. That was as high as it was necessary to go, and it used up more than half of the alphabet. Sometimes, of course, quantities occurred in which some denomination was unrepresented; in that case the space was occupied with the next letter of the Greek alphabet, which was 0 micron, or little *o*. For instance they wrote $\alpha^{\circ}\ o'\ \varepsilon''$, just as we should write 1° 0′ 5″; and that is the reason why our present character for zero happens to be the letter *o*. The sexagesimal arithmetic is attributed (possibly on insufficient evidence) to Ptolemy, chiefly celebrated for his works on geography and astronomy, which continued to be standard text-books for about fourteen centuries. After that long term of service the sexagesimal division of the radius was given up. In 1541, sixty-five years after the death of Regiomontanus, his two tables of natural sines were published; one is to radius 6,000,000; the other, to radius 10,000,000 (or, as we should say, to seven places of decimals) is similar to our present practice. A cycle of sixty years has been used in India; and the day has been divided into 60 guries, each gurie into 60 polls, and each poll into 60 twinklings of an eye. We divide the hour sexagesimally, though we have 24 hours in the day. For latitude and longitude in geography and for most angular measurements this reminiscence of the Dark Ages, the sexagesimal division, is still in use down to the second. That is now sub-divided decimally; though the incongruity of this modification is noticeable in computing; in taking the complement of an angle by subtracting two places of degrees from 90, two places of minutes from 60, two places of seconds from 60, and two places of decimals from 1.00, we have an embarrassing variety. For greater facility in figuring curves in the field it is not uncommon for engineers, neglecting degrees, to reckon in minutes and fractions of a minute. The astronomer observing the position angle of a double star sets it down in degrees and decimals. In short, people will have a division that corresponds with the prevailing arithmetic, in spite of the fact that the usual tables are calculated for a system that does not correspond with the arithmetic now established. The sexagesimal division of the circle would harmonize with a duodecimal arithmetic little or no better than it does with a decimal, as is shown by the following tabular statement:

SEXAGESIMALS.

Unit.	Successive Divisions by Twelve.			Successive Divisions by Ten.		
	$\frac{1}{12}$	$\frac{1}{144}$	$\frac{1}{1728}$	$\frac{1}{10}$	$\frac{1}{100}$	$\frac{1}{1000}$
360°	30°	2° 30′	0° 12′ 30″	36°	3° 36′	0° 21′ 36″
90°	7° 30′	0° 37′ 30″	0° 3′ $7\frac{6}{12}$″	9°	0° 54′	0° 5′ 24″
60°	5°	0° 25′	0° 2′ 5″	6°	0° 36′	0° 3′ 36″
1°	0° 05′	0° 0′ 25″	0° 0′ $2\frac{1}{12}$″	0° 06′	0° 0′ 36′	0° 0′ $3\frac{6}{10}$″

The sexagesimal division would harmonize much better with an arithmetic based on twelve, than it would with an arithmetic based on eight or sixteen; but as new tables would be required for either, this is of little importance.

After this prolix review of the whole subject of dividing the circle it is sufficiently evident that the use of twelve as a base of numeration would be adapted to expressing in simple form one-sixth part of the circumference; but that this advantage is of exceedingly small consequence.

On the other hand, eight and sixteen have the advantage over twelve in respect to several points which are worthy of notice; although they do not seem to

me sufficiently important to overcome the argument from divisibility by three.

In the first place they give still greater facility than twelve for binary subdivision. With sixteen for a base, eighths and sixteenths could be expressed with a single figure as one-half is now decimally, and with two figures we could go down to 256ths. That is carrying the thing unnecessarily far; we should be tolerably well off with twelve as a base, which would enable us to write sixteenths as easily as we now do quarters, with two figures.

Another little peculiarity about sixteen as a base of numeration, and, of course, a base of logarithmic tables also, is that the logarithms of two, four, and eight would be expressed by a single figure; for

$2^4=16$, that is, $16^{\frac{4}{16}}=2$, therefore log. 2 would be four-sixteenths.

$4^8=16$, that is, $16^{\frac{8}{16}}=4$, therefore log. 4 would be eight-sixteenths.

$8^2=16$, that is, $16^{\frac{12}{16}}=8$, therefore log. 8 would be twelve-sixteenths.

Another point of more consequence is that sixteen is a perfect square. We perceive the advantage which this would give when we apply our arithmetic to the measurement of surface. For instance, the land surveyor of our fathers, using a Gunter's chain, probably had a realizing sense of the area included in one square chain. When he sought to imagine for himself some smaller unit of comparison, supposing he had been brought up on an arithmetic of sixteen, the idea of one-sixteenth part of a square chain might naturally enter his mind. Well, that is just one square rod; four rods make one chain; therefore, sixteen square rods make one square chain. There would be a certain convenience about that which we do not get in using for a ratio in superficial measure a number which is not a perfect square; as when we go on to say that ten square chains make an acre. How long is one side of a square acre? Nobody remembers the length either in chains or any other measure. This affords comparatively little reason, however, for having a square at the foundation of our arithmetic; for it is not necessary to have the sub-units in superficial measure connected by such small gradations as the ratios of eight, ten, or twelve; it is sufficient to use the squares of those numbers. We have been getting along in the past without any intermediate unit of area between the square inch and the square foot, which is 144 square inches, or between the acre and the square mile, which is 640 acres.

I consider sixteen to be out of the question as a base for arithmetic. It would require about three times as much multiplication table as ten, and nearly twice as much as twelve.

The number eight, finally, has an advantage not possessed by any other proposed base; namely, it is a perfect cube. The value of this relates to cubical measurement and weight or other properties dependent thereon. We may illustrate again by referring to the British Imperial measures of capacity. There are eight pints in a gallon, and eight gallons in a bushel; consequently, if you have a pint measure, a gallon measure, and a bushel measure all of the same shape, all cubical, for instance, or all hemispherical, the sides or other homologous lines are in the ratio of one to two; each dimension of the gallon is half as large as the corresponding one of the bushel, and each dimension of the pint is half as large as the corresponding dimension of the gallon. If weights were in the same ratio we might have a similar relation there. The imperial gallon holds ten pounds of water. Suppose we had a ten pound brass weight, and geometrically similar weights equivalent to the pint of water and the bushel of water, of course one would be half as large in each dimension, and the other twice as large in each dimension as the ten pound or gallon weight. With any number which is not a cube a little awkwardness appears. Thus, a cord of wood is 128 cubic feet; what, then, is the length of a cubical wood-pile containing one cord? Evidently a number of linear feet expressed by the third root of 128, equal to 5+ an interminable decimal. I fail to see, however, that this is a matter of much consequence. It is very easy to imagine that a cord is of different shape from a cube. If we wish to call up a distinct picture to our minds by way of comparison, we can think of it as 8 feet long, 4 feet wide and 4 feet high. So if we had one weight or one capacity measure one twelfth as large as

another, we could make it half as long, half as wide, and one third as deep. Moreover we do not compare weights by measuring them, but we put them in the balance; and capacity measures are tested by the weight of water which they hold, in preference to any measurement. The present tendency is to sell goods by weight rather than by measure, when practicable, for the sake of fairness and accuracy. The grain business furnishes a good illustration of this; in it the bushel, originally a measure of capacity, is now defined to mean a weight.

The adoption of an octonary arithmetic was warmly advocated by Alfred B. Taylor, of Philadelphia, in his report, as a committee on weights and measures, presented to the American Pharmaceutical Association in 1859. Though I am unable to agree with his conclusions, I desire to express my admiration for his thorough discussion of the subject, and to acknowledge my indebtedness to him and to the authorities whom he cites for a large portion of the material of this paper.

THE DENSITY OF SATURATED STEAM.

By JOHN W. HILL, M. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE density of steam, as the term is commonly used by engineers, is the weight of a unit of volume, as compared with that of water at maximum density; and the specific or relative volume, is the measure of expansion of a unit of water, converted into saturated steam: The density and specific volume are reciprocal quantities, thus

$$D=\frac{1}{V}$$

when V represents the ratio of expansion of a unit of water, converted into saturated steam at pressure P.

Saturated steam, as the writer apprehends the term, is in itself an indefinite expression, from the fact that it has been variously used to denote different conditions of steam; as used in this paper it indicates heat saturation—that is, steam charged with the latent heat due the temperature and pressure of evaporation; any addition of heat elevating the temperature and superheating the steam, and any reduction of heat converting a portion of the steam into liquid water. Thus saturated steam cannot receive additional heat without becoming gaseous, and cannot part with heat without condensation, pressure and volume unchanged. The density of liquid water at different temperatures, and the law of dilatation, by changes of temperature, has been determined with great exactness by various experimenters. Likewise the laws of expansion of gases according to Mariotte and Gay Lussac, modified by the later experiments of Regnault, can be accepted with perfect confidence. When it becomes necessary, however, to resolve a given volume of steam into its constituent liquid water, at any temperature, the reduction is by no means an easy one: from the fact that experimental data is wanting, at present, to determine the specific volume, or density of saturated steam at various temperatures of evaporation.

Many difficulties beset the experimental determination of this problem, one of which is that suggested by Mr. Charles F. Porter in his treatise on the steam engine indicator, that, "the expansion and contraction of volume consequent on changes of pressure, and those consequent on the changes of temperature cannot be investigated separately." The truth of this is obvious, for with a reduction of volume of a given quantity of steam, there is an increase of pressure and density, due to forcing the molecules of the mass into closer contact, at the same time the work expended in overcoming the resistance of the mass to reduction of volume is reproduced in the steam by an elevation of temperature, if the previous volume were saturated steam, or by an evaporation of the liquid water, if the previous volume was inferior to saturated

steam. If the initial quantity were saturated steam, the heat due to the work expended in reducing the volume, would appear as a super-heat, and the dilatation due the super-heat, could be determined by Gay Lussac's law; conversely if the initial quantity were inferior to saturated steam, the heat due to the work expended in the reduction of volume, would appear as latent heat in the atoms of liquid water unevaporated in the steam. In the first instance, we would have an increase of pressure and temperature, and in the second instance, an increase of pressure and density, due to distinct and separate causes, and, as Mr. Porter asserts, the investigation of each cause cannot be conducted independently.

According to Rankine the dilatation of a perfect gas is represented by the following law

$$\frac{P.V}{P'V'}=\frac{461.2+t}{461.2+t}$$

Thus if the absolute temperature be doubled, the volume under constant pressure will be doubled, or the pressure under constant volume will be doubled. But Regnault's experiments have shown the coefficient of dilatation to be greater under constant pressure than with constant volume.

This law in a modified form has been used to calculate the relative volume of steam. When Regnault was commissioned to investigate the laws and phenomena of steam, as affecting its useful application, the density formed no mean element of the work. But while his experiments have determined with great precision the relations of temperature, and pressure, of saturated steam; together with the specific heat under constant pressure and constant volume, and the thermal value of a unit of steam (by weight) at different temperatures of evaporation; his investigations it seems never extended to a determination of the density.

Rankine has computed the density of steam from its chemical composition, upon the assumption that saturated steam is a perfect gas: thus two volumes of hydrogen, combine with one volume of oxygen, forming two volumes of vapor of water, having a density of .622 as compared with air.

The weight of a cubic foot of dry air at 32° Fahr., and, under pressure of one atmosphere, is usually taken at .080728 pounds: hence weight of cubic foot of vapor of water at same temperature and pressure;

$$D=.080728\times.622=.050213 \text{ pounds.}$$

As suggested by the author, this quantity (.050213), is to be used in calculation only, since saturated steam cannot exist under the assumed conditions: [the temperature of evaporation under pressure of 14.696 pounds (one atmosphere) being 212° Fahr., and, the pressure of evaporation at 32° being .089 pounds.]

If the gaseous theory of steam were correct, then the density under known conditions of pressure and volume could be determined by the Mariotte law. But the density of steam, under specific conditions, is known to be greater than the density assigned by theory, and such limited experiments as have been made in this direction, which while they do not establish other than empirical formulæ, they have determined beyond a doubt, that the laws governing the density of perfect gases, will not apply to saturated steam.

Regnault observes that, "mechanicians admit for the most part that the weight of a cubic meter of vapor, of given pressure and temperature, may be calculated by applying to it the law of Mariotte, and the law of uniform dilatation of gases. But these laws are not rigorously exact even for permanent gases, and it is to be feared they may be completely false for saturated vapors."

Rankine has also computed the density of saturated steam from the latent heat, and suggests that "the density of the vapor of water as computed from its latent heat of evaporation, is greater than that corresponding to the perfectly gaseous state;" again, "for steam at low pressure the difference is trifling but increases rapidly as the pressure increases." Fairbairn has made the density of saturated steam the subject of direct experiment upon which the well known Fairbairn and Tate formula is based. The principle upon which the experiments were conducted is described as follows:

"The density of steam is ascertained

by placing in a glass globe of measured capacity, and exhausted of its air a weighed quantity of water."

"The globe is then placed in a bath and raised in temperature until the entire weighed portion of water is converted into steam; the temperature at which this happens is noted and we have thus the three elements for calculating the density, the temperature, the volume, and the weight from experimental data."

The apparatus employed by Fairbairn was extremely delicate, and were it not that certain doubtful elements unnoted at the time of the investigations entered into the subject, it is possible that these experiments, while not conclusive in themselves, would have formed a basis for more extended and determinate investigations into the density of saturated steam.

The first objection to a law based on Mr. Fairbairn's experimental results is the assumption, that the steam in the measured glass globe was saturated steam at the time test observations were made. No attempt was made (at least none was recorded) during the experiments to determine whether the steam was saturated; and the conditions under which evaporation occurred were such as to leave room for grave doubts as to the precise condition of the steam, at time test observations were made. It is well known that steam is capable of holding in mechanical suspension a large percentage (by weight) of water unevaporated, and at the same time, as observed through a glass boiler, appear transparent. From experiments by the writer upon steam in a clear flint glass boiler, it appears that a primage of 20 per cent. by weight, can exist and not affect the transparency or ethereal appearance of the steam. At the present time it is the practice with engineers in charge of nice experiments to provide especial apparatus to determine the percentage of liquid water contained in the steam, and any economy test of engine or boiler, or capacity test of boiler, is worthless unless this data is obtained. Upon the other hand, steam may be at superheat, and, it is equally important that this fact be known and its value determined, in such tests as are to be of permanent value.

Fairbairn's apparatus was such as to preclude the possibility of superheat in the test quantity of steam. And (in the writer's opinion), as he conducted his experiments it would have been impossible to produce saturated steam. If this be true then any law based on these experiments is not a law in fact, and the Fairbairn and Tate formula can be reliable only under conditions similar to those existing during the experiments. And as no record was made of the quantity of the steam experimented on it is a very uncertain question as to where this formula will apply.

The second objection to the Fairbairn methods for determining the density of steam, is in the use of glass globes. It is well known to those who have had occasion to use glass boilers for experimental purposes, that the application of heat alone will be insufficient to convert all the contained water into steam, the attraction between the glass and the water being sufficient to retain in contact with the glass, a portion of the water unevaporated. Rankine observes that "if in experiments on the density and expansion of steam glass vessels are used, a new cause of uncertainty is introduced, by the fact that the attraction is sufficient to retain in the liquid state, and in contact with the glass, a film of water at a temperature at which but for the attraction of the glass it would be in the state of steam."

The formula deduced by Mr. Tate from Fairbairn's experiments is

$$V = 25.62 + \frac{49513}{I + .72}$$

where V represents the ratio of expansion of a unit of water, converted into saturated steam, at I inches of mercury.

From the experiments of Arago and Dulong, Pambour has deduced the following formula

$$V = 37.3\frac{458 + t}{p}$$

where t represents temperature of evaporation corresponding to p pounds (absolute) pressure. This is a popular formula for computing the relative volume of saturated steam, and will be found in many standard text-books. Haswell uses it in his manual for engineers, but substitutes 76.5 as the multi-

plier in the second member of the equation, and p is taken in inches of mercury.

This author also offers a formula for the determination of the relative volume of steam based on Gay Lussac's law, but as this law relates to perfect gases, and as steam is not a perfect gas at saturation, it is not clear how it can be made to solve the problem of relative volume. The dilatation of steam above saturation or superheated steam can be determined by Gay Lussac's law; but the ratio of expansion of a unit of water, converted into saturated steam, appears to the writer to be beyond the reach of this law.

According to Weisbach (Vol. 1, Art. 392), "Gay Lussac's experiments repeated more recently by Rudberg, Magnus and Regnault, have shown that for the same density the tension, and for the same tension the volume, of one and the same quantity of air increases with the temperature." Upon the assumption, however, that "for the same tension and temperature, the density of steam is about § of that of atmospheric air. Weisbach proposes the following formula for the density of steam

$$D = \frac{.050475}{1 + .00204\ (T - 32)}$$

$$\frac{P}{14.7} = \frac{.003434\ P}{1 + .00204\ (T - 32)}$$

where D equals the weight per cubic foot of steam, at pressure P. The objection to this formula, is that the density of steam does not obey the gaseous laws; and Fairbairn's experiments, which while they do not establish a precise law for the density of saturated steam, do show in the language of the experimenter, that "the density is greater than that given by the gaseous laws, even at low temperatures."

Computing the density of steam by Rankine's formula, based on the latent heat, proves that the density is greater than that assigned by the gaseous laws.

The necessity for further experiments, and the construction of formulæ that will relieve this problem of some of the uncertainty that now surrounds it, is desired by all having occasion to deal with the question of density. And no doubt it will be determined at a future period, very much as Regnault has determined the relations of temperature and pressure and specified heat by steam.

MODERN BLASTING EXPLOSIVES.

From the "London Mining Journal."

At no period in the history of the civilized world has the adage "Time is money" been more forcibly illustrated than in the actual demand by the mining community for the strongest explosives —or, in other words, for the explosive which will produce the greatest effect with the smallest labor or time employed in boring holes to receive the same, or in tamping. Again, the military engineer keeps himself *au fait* of all new destructive agents which, under the smallest weight, will do the most mischief, the most essential point in using explosives in the field being to place the charge on the proper spot at the proper time, which means quick carriage and hence small weight. Chemistry and engineering have not been slow to respond to the demand, and amongst the host of explosives which have been brought forward at different times there are some two or three which have attained a decided pre-eminence, each in its way. We refer to dynamite, tonite, and compressed guncotton.

The literature of modern explosives exists only in the shape of papers read at institutions, and pamphlets from scientific specialists. We will endeavor in the following lines to gather a few notes which we believe may be of some value both to the scientific and the practical man. It is not our intention to dwell at length on what may be called the earlier history of the explosives under consideration. We will only call to mind the points of interest which have marked their progress towards practical utility. It is well known that guncotton

was first introduced to the public by Schonbein in 1846. Great things were expected from the discovery, and yet in a few years, after a brief but eventful career, guncotton was relegated to the laboratory shelf, and amongst the sufficient causes for such a proceeding we may mention the inability of the makers to produce a stable article, and also the enormous bulk occupied by a charge of the explosive, as well as its inherent property of disengaging upon explosion a large amount of carbonic oxide gas, which, in close workings, is not only objectionable on account of health, but absolutely dangerous as fire damp. Ways and means as ingenious as numerous were tried in divers countries to master this promising but crude invention, but the only improvement, partially successful was for a long time obtained in nitrating the guncotton with saltpetre. This material reduced the carbonic oxide and added considerably to the strength of the guncotton, but the fumes resulting must have been very inconvenient, as the carbonate of potassa produced very readily remains in suspension in the atmosphere for a long time, not to mention the almost inevitable presence of cyanide of potassium, but the most potent objection to its use was its liability to explode spontaneously.

Things were in this condition, and ordinary gunpowder continued to reign supreme, when Sobrero somewhat before 1860 introduced his nitroglycerine. New hopes were raised, and as a consequence money, labor, and ingenuity were devoted to the work, but nitroglycerine, like guncotton and, indeed, all great inventions, had a hard fight before it could inspire confidence in the public, for the material as then made was very unstable, and even when pure—chemically stable, if we may use that expression—it was liable to disruption from physical causes. One of these, still unexplained, happens during the passage of the frozen nitroglycerine from the solid to the liquid state, as if the crystals were suddenly broken by a too sudden application of heat, as in the well-known decrepitation of common salt; a similar theory has been used to explain explosions which sometimes occur with fulminate of mercury when this substance is put to dry, which, although quite pure, may explode at a temperature far below its normal exploding point.

Now we come to one of the important epochs of invention—the discovery of dynamite by Mr. Alfred Nobel. Dynamite is nitroglycerine mixed with an earthy absorbent, the result being a plastic instead of a liquid substance, and therefore more manageable, the tendency of the nitroglycerine to spontaneous explosion in thawing being considerably reduced by reason of the modification in the structure of the compound. The nitroglycerine used in the manufacture of dynamite can now be made quite pure, so the enormous consumption of the produce is justified in the absence of any competing explosive. Let us hope that Mr. Noble will by his intended new admixture entirely destroy the causes which bring about the terrible calamities frequently reported in the papers, such as that at Parma, and at Bangor quite recently, where dynamite exploded while being thawed. During the period of the progressive success of nitroglycerine and dynamite, guncotton had a hard struggle for existence, the best, if not almost the only, friend of the latter substance being Professor Abel, F.R.S., who with a clear practical mind, recognizing that no inherent property of guncotton stood in the way of its practical employment, set himself to solve the problem of its utilization. First he cut the guncotton fiber into pulp, thereby reducing its bulk and improving the stability of the guncototn by permitting a more thorough washing. It was then found that the power of exploding by a flame was very much reduced, in consequence of the closer texture of the compressed dry pulp, but as Mr. Nobel had successfully applied the detonator to his dynamite, so did Mr. Brown, of Woolwich, succeed in producing a first-class explosion with guncotton thus detonated.

These are splendid achievements, and the next step—nitrated pulped guncotton—was actually making its appearance when occurred the Stowmarket calamity, which drove all confidence away for a time. It was then proposed to use the pulped and compressed guncotton in the wet state, as it was found that it could be exploded in this condition by using a strong primer of dry guncotton; indeed, large quantities are now being employed

under this condition, but of course all thoughts of using a nitrate with it was abandoned, as saltpetre does not answer in conjunction with wet guncotton. This was very regretable, as it is well known that by nitrating guncotton its strength, as measured by the best energy, it can produce, is increased fully thirty per cent., and moreover, no carbonic oxide is produced—a very important item in ill-ventilated workings. Unnitrated and wet compressed guncotton is mainly used for military and naval purposes, on account of its safety over dynamite and its remaining unaltered by climatic changes; at all events it is relatively easier to keep it from freezing. Miners, however, who buy explosives for profitable purposes, will not use it in any quantity. There remained, therefore, ample room for further progress in dry nitrated guncotton compressed to the smallest bulk. This has been obtained in an explosive called tonite, manufactured by the Cotton Powder Company of Faversham. The remarkable results obtained by the officials of that company in producing this explosive renders unnecessary any apology on our part for explaining at some length what these results are, and how much the mining community, and, indeed, the nation, may be benefited by their labors. About 1873 the Cotton Powder Company, under a somewhat different name, commenced operations, their object being, amongst other things, to produce nitrated guncotton according to the terms of their license, and, commencing so soon after the great catastrophe at Stowmarket, it required no small amount of courage to attempt the manufacture of apparently a similar explosive, although it offered a most promising reward to success.

Tonite or cotton powder is now well known to all mining engineers under the shape of a dense dry cartridge; it is generally waterproofed, and is not altered by any conditions of temperature. The density of tonite is about 1.50—that is, it goes into the same space as dynamite, and in about two-thirds that of compressed guncotton. The base of tonite being guncotton the first care of the manufacturers was to devise practical means of purifying that substance, which being produced of ordinary cotton steeped in mixed sulphuric and nitric acids contains in its crude state some portion of that mixture, with other nitro compounds. The free acids are easily eliminated by washing with water, with or without alkaline addition, but the nitro compound impurities—nitro-starch, nitroglycerine, and other products of the resins, sugar, and impurities of the original cotton—are not so easily got rid of, being insoluble, and partly imprisoned in the capillaries of the cotton fibre. It had been long known to the chemical student that inferior nitro compounds are partly destroyed in boiling water, and that ammonia is a very powerful reducing agent of these compounds. It only needed practical hands to unite the processes. As the washing plant now stands at Faversham any quality of guncotton can be purified as to its dangerous impurities in about two hours, and the same process applies whether the fibre is very long or very short. This process has been in operation for about five years with perfect success, and we understand that it is partly followed at the Government works at Waltham Abbey. It can at all events be assumed that Prof. Abel has satisfied his mind about the value of such washing or boiling process, for it will be remembered that at the last meeting of the British Association, at Portsmouth, he said that guncotton could now be made quite reliable.

From pure guncotton to dry nitrated powder there is only one step—choose the proper nitrate. Before settling this point we may dismiss chlorate of potash, the most powerful of all available oxidizing agents. It is known that guncotton used with the proper quantity of chlorate of potash is superior as a blasting agent to the best nitroglycerine, but, like this substance, it is liable to explode under the slightest rough usage. The available nitrates for mixing with guncotton are the nitrates of ammonia, potassa, soda, baryta, strontia, &c. The nitrates of ammonia, soda, and to a certain extent strontia, are deliquescent, and have never been used with any success for a length of time; all these nitrates except that of baryta are very soluble, and thereby interfere with the manufacture, and, moreover, give very disagreeable fumes in the mines. In short, after many trials nitrate of baryta was definitely chosen. *Prima facie* it

is the best suited to the purpose, as containing more earthy base in a given weight, but if we bear in mind that in mining the space occupied by the explosive is more an object than its actual weight, and as it is possible by the use of nitrate of baryta to lock up under the very smallest possible space a larger amount of energy than by the employment of any other nitrate, the choice then appears justified. There is another point to be considered in favor of tonite —its economy of manufacture. Tonite can be made at forty to fifty per cent. less cost than guncotton, and of thirty per cent. greater strength. In these times of heavy military and naval expenditure it might be well worth considering what would be the economy to the nation in substituting tonite for ordinary wet guncotton, considering that the former is quite as safe, if not safer, than the latter, for wet guncotton stored in South America has lately given cause for serious doubts as to its stability. We have said enough for the present to show that the question of a blasting agent is being vigorously studied, and that progress has been made; there are, however, a great many other very important points which will suggest themselves to the consumer, such as those under the head of plastic explosives *v.* solid cartridges, &c. These have been well tested, every experiment conforming with those thermodynamic theories, which teach us that heat alone is force irrespective of space, and as the miner's chief object is to economise space, to minimise his boring, and the issue as between solid tonite and plastic dynamite is only about five per cent. of space, when all the pleas are considered, the question may be pronounced practically settled against dynamite in favor of its younger cousin tonite, against the daughter of nitroglycerine in favor of the offspring of guncotton.

REMARK ON PROPOSITION IV OF "NEW CONSTRUCTIONS IN GRAPHICAL STATICS."

By WM. CAIN, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

PROF. EDDY'S note on this proposition in the May number of this Magazine suggests the following confirmation of this fundamental law.

Wm. Bell has shown (see "Stresses of Rigid Arches, &c.," Van Nostrand's Magazine Vol. 8, p. 199) that "the *neutral line* of the arch rib, having been divided into equal lengths," the conditions that an arch rib be "fixed at the ends" are,

$$\Sigma M = o,\ \Sigma My = o;$$

and he should have added his eq. (5) when $v = o$ $\therefore \Sigma Mx = o$.

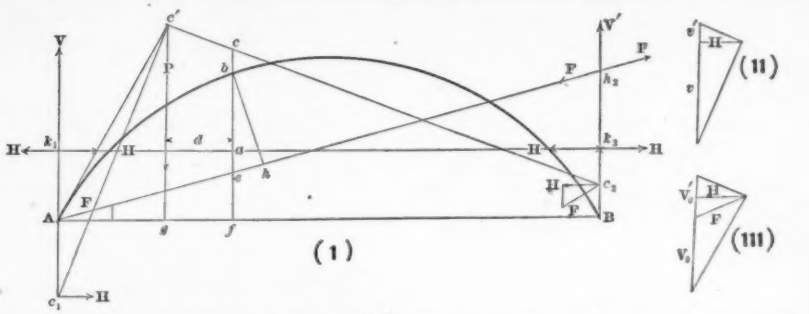
For very flat arches, the *span* may be divided into equal parts to give a near approximation which plan was adopted by Prof. Eddy, (see April No., 1878).

First consider the arch ADB as "fixed" at the abutments A and B. The resultant of the vertical reaction V and horizontal force H cannot pass through A, as there would then be no moment there to cause fixity, but through some point c_1. Similarly the resultant of V' and H at right abutment passes through c_2. Now we do not disturb the equilibrium by applying at k_1 and k_2, $+H$ and $-H$ acting horizontally in line k_1k_2, but we thereby transfer H at c_1 and c_2 to k_1 and k_2 and add the moments $H.\overline{k_1c_1}$, $H.\overline{k_2c_2}$ at A and B respectively; so that the moment about a point b, d to right of weight P, x to right of k_1 and y vertically above k_1 is,

$$M = (Vx - H.\overline{k_1c_1} - Pd) - Hy \quad . \quad (1)$$

The term, $Pd = o$, for points to left of P.

The term $(Vx - H.\overline{k_1c_1} - Pd)$ is the moment at b of the rib acting as a continuous girder with end moments at A and B; $H.\overline{k_1c_1}$ and $H.\overline{k_2c_2}$ respectively. In fact, if there were no moments at A and B, then $c_1c'c_2$ with a closing line c_1c_2 would be the equilibrium polygon. Assume $H.\overline{k_1c_1}$ to be the moment re-



quired at A to "fix" the end of the rib *acting as a girder*, and write $M_c = Vx - H.k_1c_1 - Pd$ = moment due to loads, &c., as for a girder; also write $M_d = Hy$ = moment due to H acting at k_1.

$$\therefore M = M_c - M_d \quad . \quad . \quad (2)$$

Now $k_1c_1cc_2k_2$ is the equilibrium polygon of the rib acting as a girder, $\overline{k_1k_2}$ being the "closing line," as will be proved: Now having assumed $H.\overline{k_1c_1}$ to produce bixity at A, the moment required at B to effect the same object at that point can have but *one* value found by taking moments about B. Now the supposed forces acting along the sides of the equilibrium polygon k_1c_1, c_1c, cc_2, k_2c_2, being balanced as seen by reference to force diagram, leaves

V, P, V', and couples $H.\overline{k_1c_1}$ and $H.\overline{k_2c_2}$ in equilibrium.

$\therefore$ Taking moments about c_2, we get

$$H.k_2c_2 = Vl - H.\overline{k_1c_1} - P.GB$$

the same value as we should find by the principle of moments. Hence k_1k_2 is the true closing line for the arch rib acting as a girder fixed at the ends. It is also the closing line of the rib considered as an equilibrium polygon, whose moments $M_d = Hy$ are entirely due to the horizontal thrust acting at k_1. So that if the equilibrium polygon due to the rib acting as a girder could be drawn with a pole distance H and with $k.k_2$ for its closing line, then from eq. (2) the ordinates intercepted between these last two polygons multiplied by H give the real bending moments acting on the arch.

We have previously seen that for a rib fixed at the ends we must have the conditions fulfilled.

$$\Sigma M = o,\ \Sigma Mx = o,\ \Sigma My = o \quad . \quad (3)$$

Now the rib acting as a girder fixed at the ends by the moments applied must satisfy the conditions.

$$\Sigma M_c = o,\ \Sigma M_c x = o,\ \Sigma M_c y = o \quad . \quad (4)$$

whence

$$\Sigma(M_c - M) = o,\ \Sigma(M_c - M)x = o$$
$$\Sigma(M_d - M)y = o$$

whence by eq. (2) we have also,

$$\Sigma M_c = o\ \Sigma M_d x = o,\ \Sigma M_d y = o \quad . \quad (5)$$

In words, these eqs. show that the closing line k_1k_2 must be determined "from the same considerations respecting supports, etc.," for the curve c as the curve d. (Fig. 2 of "New Constructions, &c.")

Prof. Eddy has ably shown how, from these equations, the curve of moments M is finally drawn.

It may be remarked that the end moment $H.\overline{c_1k_1}$, which was assumed, is readily determined by the conditions (4) of a girder fixed at the ends. The pole distance H is then found by the conditions (3), whence the value of c_1k_1 follows, giving a starting point for the true equilibrium curve which is then drawn.

It is seen from the foregoing that we first have to prove that $k_1c_1cc_2k_2$ is the equilibrium curve, to pole distance H, whose moments are M_c. Next that the arch regarded as an equilibrium curve to a closing line k_1k_2 and pole distance H gives the moments, $M_d = Hy$; whence from eq. 2, $M = M_c - M_d = H\times$ difference of ordinates from k_1k_2 to rib and equilibrium polygon c.

It is seen that because eqs. (3) and (4) are true, that (5) is always true; which thus imposes similar conditions for the closing line of polygons c and d to fulfill as enunciated in Prop. IV.

If the arch is not fixed at one or both ends; still, whichever of the conditions (3) hold, give corresponding conditions in (4) and (5).

When the arch rib has end joints, as there can be no moments there, the points k_1 and c_1 are found at A, and the points k_2 and c_2 at B; when Prop. IV evidently holds.

If one end of the rib is fixed and the other jointed, we may prove in an elementary manner, that Prop. IV is applicable as follows:

Suppose the true equilibrium polygon $Ac'c_2 \ldots$ drawn. Let the force $F = H \sec. h_2 AB$: and conceive applied at A and c_2, two vertical equal and opposed forces, whose value is the same as the vertical component of F. This does not destroy equilibrium, but replaces V and H at A by V_0 and F, see Fig. 3; similarly H and V' at c_2 are replaced by F and V_0', calling V and V' the real reactions at A and c_2.

Now if we apply at h_2, $+F$ and $-F$, as drawn, we do not affect equilibrium, but we thereby transfer F at c_2 to h_2 and add the couple, whose moment $= F \times h_2 c_2 \cos. h_2 AB = H.h_2 c_2$.

If we assume that this couple is of sufficient intensity to fix the end B of the *rib acting as a girder* then the equilibrium polygon for the girder is $Ac'c_2 h_2 A$, as is evident by "following round" the force polygon (III): so that for a point c, $M_c = H.\overline{ec}$.

Let us take moments about the point b

$$M = (V_0 x - Pd) - F.\overline{bh}$$
$$\therefore M = M_c - H.\overline{be} = H.\overline{bc}$$

as before found.

The assumed moment at B can be obtained as Prof. Eddy has shown from the second of conditions (3). A similar condition in (5) determines the closing line Ah_2 for the curve of the arch considered as an equilibrium polygon with the same horizontal thrust H.

We have thus established Prop. IV for various styles of arch, it is believed, in an elementary manner.

It is stated by Prof. Eddy thus:

"*Prop. IV.*—If in any arch that equilibrium polygon (due to the weights) be constructed which has the same horizontal thrust as the arch actually exerts; and if its closing line be drawn from consideration of the conditions imposed by the supports, etc.; and if furthermore, the curve of the arch itself be regarded as another equilibrium polygon due to some system of loading not given, and its closing line be also formed from the same considerations respecting supports, etc.; then when these two polygons are so placed that their closing lines coincide, and their areas partially cover each other, the ordinates intercepted between these two polygons are proportional to the real bending moments acting in the arch."

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia. — A meeting of the Club, held April 20, the Secretary read a paper by Mr. Wm. F. Biddle, entitled "Notes on the Location and Construction of a Mining Water Works in Venezuela." The work described was that of locating and constructing a pipe line to take water from the Orinoco River, three miles inland and 285 feet high to a stamp mill at the outcrop of a rich quartz vein, the mill having been built there in the disappointed expectation of getting water by sinking a slope to a moderate depth on the vein. The paper was fully illustrated by profile and sketches showing how the work was done.

The line was laid with four-inch and five-inch cast iron pipes, and with wooden troughs seven inches wide by six inches deep, two Worthington duplex pumps were used to operate the line, one located at the river and the other 5,800 feet from it. The starting point in both the preliminary and final surveys was the second pump. In fact the whole plan grew out of the remarkable advantages afforded there for delivering the water on top of a high plateau through a comparatively short discharge pipe. The first pump discharged through a pipe 464 feet long, with a lift of 160 feet, into troughs which followed the contour of the hills, with a falling grade of $\frac{3}{10}$ per 100 feet. Before reaching the second pump two ravines were crossed by means of inverted syphons. In calculating the heads for these the wide differences between the formulae of Weisbach, Etelwein and others became very apparent. The comparison of these formulae and notes on Kutter's formulae for open channels formed a very valuable and interesting feature of the paper.

Mr. John Bogart remarked that the paper was one of very great interest, and that it brought out some points upon which engineers are in great need of practical information. A paper by Gen. Theo. Ellis, which he had read at the New Orleans meeting of the American Society of Civil Engineers, showed the same unsatisfactory results in a comparison of formulae relating to the flow of water in small channels.

Mr. Henry C. Lewis made some remarks in regard to a deposit of coal in Montgomery County, to which he had referred at the meet-

ing of the Club held March 16th. Upon visiting the locality he had found it one of very great interest. The deposit of coal does not occur at the lower boundary but toward the center or upper center of the Mesozoic red sandstone. The sandstone has a flat dip S.W., and shows a low anticlinal fold.

Mr. Ingham remarked that there are several questions connected with the Mesozoic formation which are of very great importance, and which it is hoped will be solved by the present Geological Survey of the State. The formation is broken up by numerous trap dykes which are often accompanied by minerals of economic importance. In many places the sandstone has been forced up into dome-shaped folds, where the trap dyke has not reached the surface. Such was the case at the Sellersville Tunnel and was the cause of very great expense to the N. P. R. R.

Mr. Percival Roberts, Jr., called the attention of the Club to some notes on an "Empirical Formula for estimating the Strength of Wrought Iron Beams, Channels, &c."

Mr. Roberts thought the formula might be found convenient for making rough calculations on account of its simple form.

Considerable discussion followed in regard to the various reasons for variations in the strength of manufactured iron, methods of testing, &c.

Mr. Bogart called especial attention to the work of the U. S. Board for testing iron, steel and other metals. Congress has appropriated, and the Board has expended nearly one hundred thousand dollars. A clause in the Act creating the Board provides that it shall cease when the appropriation shall have been spent. The Board have gone through enormous preliminary labor and have cleared the ground for effective work. If Congress refuse now to continue the appropriation, and the Board is dissolved, the work already done will be measurably lost, and a new Board would have to go through much of the preliminary work again, In the meanwhile we will go on for years groping in the dark for the knowledge which the Testing Board is organized to procure—these years being marked, at short intervals, by disastrous blunders of engineers, architects, builders and mechanics. On the other hand, if the Board is sustained, the knowledge obtained will be conducive to the great material interests of our people, and it will enable us to design and execute works creditable to ourselves and to American engineering.

Upon motion of Mr. Ingham, a Committee was appointed to memorialize Congress, asking a continuation of the work of the U. S. Board for testing metals.

IRON AND STEEL INSTITUTE — REPORT OF COUNCIL FOR THE YEAR ENDING DECEMBER 31, 1877.—The Council, in presenting their Ninth Annual Report, have much pleasure in being able to congratulate the members on the continued prosperity of the Institute.

The total number of members exceeds nine hundred. There continues to be a steady accession of new members, contributed both by this and foreign countries, forty-seven being proposed for election at this meeting. The Council refer with much gratification to the increase of foreign members, showing, as it does, that the objects and the proceedings of the Institute are fully appreciated by Continental and American metallurgists.

At the two general meetings, held during 1877 in London and Newcastle, papers were read which in the opinion of the Council were well calculated to promote the objects and maintain the prestige of the Institute. The subjects considered at these meetings were:

Paper by Mons. F. Gautier, Paris. On Solid Steel Castings (Acier sans souflures).

Two papers by Mr. I. L. Bell, M.P., F.R.S. On the Separation of Carbon, Silicon, Sulphur and Phosphorus in the Refining and Puddling Furnace, and in the Bessemer Converter.

Paper by Mr. E. Riley, F.C.S. On the Estimation of Manganese and Iron in Iron Ores and Spiegeleisen.

Paper by Mr. E. Riley, F.C.S. On Chromium Pig Iron made by the Tasmanian Iron Co.

Paper by Mr. Henry Simon. On Chaudron's method of Shaft-sinking through Water-bearing Upper Strata.

Paper by Dr. C.W. Siemens, F.R.S. On some further results obtained by the Direct Process of Manufacturing Iron and Steel.

Paper by Mr. R. Howson. On Mechanical Puddling.

Paper by Mr. A. L. Steavenson. On the Manufacture of Coke in relation to the Iron Trade of the North of England.

Paper by Mr. G. C. Greenwell. On the Geological Features of the Great Northern Coal Field.

Paper by Mr. Chas. Wood. On Four Years' Improvements in the Utilization of Slag.

Paper by Mr. A. Thomas. On the latest Improvements in Belgian Merchant Rolls.

Paper by M. Gautier, C.E. On results of Experiments with Cannon Manufactured from Steel without Blows.

Papers by Dr. Percy, F.R.S. On the Protection from Atmospheric Action which is imparted to Metals by a Coating of certain of their own Oxides respectively; and on the cause of Blisters on Blister Steel.

The success of the meeting held at Newcastle in September amply justified the selection of that place by the Council, whose best thanks are hereby conveyed to the Local Reception Committee, to the Local Hon. Secretaries, to the Owners of Works in the locality, to the North-Eastern Railway Co., to the Cleveland Ironmasters, and to all others who helped to make the occasion agreeable. The attendance of members at Newcastle was larger than at any previous meeting of the Institute, and the large number of visitors who sought admission proved the interest taken in the proceedings.

The receipt of an invitation from M. Tresca, on behalf of the Société des Ingenieurs Civils, to visit Paris in the ensuing summer, and the concurrent holding of the International Exhibition in that city, have induced the Council to recommend that the next autumnal meeting should be held in Paris.

IRON AND STEEL NOTES.

THE MANUFACTURE OF IRON AND STEEL.—No man better deserves the warmest thanks of our ironmasters than Mr. I. Lothian Bell, seeing that for years past he has devoted a great deal of time to finding out the best means of producing pig with the smallest consumption of fuel. In conjunction with other North Country makers, he has succeeded, for he tells us that where not so long since 70 cwts. of coal were required to make 1 ton of pig, the same is now accomplished with from 41 to 45 cwts. That is with respect to the Middlesborough ironstone, which is by no means rich, giving only about 30 per cent, of metallic iron, whilst for Spanish, and other ores yielding 50 per cent. of iron and upwards, the quantity of coal for smelting would be probably 5 cwts. per ton of pig less. This great economy in fuel in the manufacture of iron has been of the greatest benefit to the country, as it has enabled us to supply even continental makers with pig at a less price than they could produce it. But Mr. Bell has gone further, and in another direction has endeavoured to produce iron from Cleveland stone so clear of phosphorus that it can be readily converted into Bessemer. This is the great difficulty to be overcome in the conversion of such ores into steel fit for rolling, and Mr Bell appears to have gone into it most thoroughly, and if the results are not all that could be desired, he is certainly on the high road to success. For the purpose of freeing the pig from its impurity, Mr. Bell washes out the phosphorus by means of oxide of iron, and the question naturally enough arose as to whether or not the process would be too costly to pay. It appears that about 10 cwts. of oxide of iron is used with every ton of pig, and if that would cost 10s. then it was considered that it would scarcely pay. But it is quite probable that a much less quantity of oxide of iron may be found in future manipulation to attain the desired results. One of the most important points to be realized is as to the quantity of phosphorus that could be left in a steel rail without injuring it in any way, for as we all know that it is the great enemy of both the Bessemer and open-hearth manufacturers, yet for some purposes even in steel it may be a valuable ingredient. Formerly spiegeleisen was used to decarbonized Bessemer steel to impart manganese to the oxygen of the oxide of iron formed in the Bessemer process, but now it is adopted not only to remove the oxygen, but to mix the manganese with the steel; and it has been asserted by a high authority that if the proportions of silicon and phosphorus were sufficiently low, and the carbon did not exceed a third of 1 per cent., manganese to the amount of three-quarters of 1 per cent. would give the resulting product a high degree of toughness and hardness combined—a degree of suitableness for rails which no proportion of either carbon or manganese not associated could impart. But we are told that in the Great Northern Bessemer rails as much as 0.274 per cent. of phosphorus has been found, but the question really appears to be as to what amount of phosphorus a rail would stand without impairing it in any way. This satisfactorily determined, the experiments would be resumed by Mr. Bell with greater certainty of succeeding. He would also be able to define accurately the different proportions of the various ingredients that are necessary for bringing out a certain quality of steel, which can scarcely be said to be the case at present, although we are frequently told as to the elasticity and resistance of steel by testing.

But that steel is about to undergo another revolution is pretty evident, for at the recent meeting of the Iron and Steel Institute, on the discussion of Mr. Bell's paper, Mr. Snelus said that six years ago he took out a patent for converting Cleveland pig into steel, and in reducing the phosphorus in it to under 0.1 per cent., using limestone for the lining of his furnace. He said he had such confidence in his patent that he intended renewing it, although it was six years old. This process no doubt would be less expensive than that of the oxide of iron, but there appears to be some difficulty in the carrying out of the process with respect to the furnace; but, if all other details can be successfully carried out, no question but what that will be easily overcome. But a still greater surprise was in store for the members of the Institute by Mr. Sidney Thomas declaring that he had succeeded in entirely removing phosphorus by the Bessemer converter. This was certainly a startling announcement to make, and equally so was the statement that he had the results in his pocket of more than 100 analyses of different experiments for the very small quantity of 6 pounds up to 10 cwts., and all the results carried out the theory with which he originally started. In the worst results 20 per cent. of phosphorus was removed, and in the best 99.9. This latter result one would think would be sufficient for anything, and we feel sure the particulars will be looked forward to with much interest by our ironmasters and Bessemer makers. We have, however, three distinct processes before us by which the phosphorus can be eliminated from Cleveland iron, and the latter converted into Bessemer steel. As to the comparative merits of each process there is not sufficient data before us to give an opinion, seeing that each proposal may be said as yet to be in only an embryo state. But before long it is to be hoped detailed results of further results will be given, when the public will be in a position to judge of their respective merits. In the meantime we understand Mr. Bell will proceed with his experiments, and without ignoring the claims of others in the same field to every consideration, we believe we only echo the feeling of all persons connected with the iron and steel trades in wishing him every success.

RAILWAY NOTES.

EXPERIMENTS ON STEEL RAILS—BY J. VAN L HAMEL.—These experiments were made on steel rails ordered for the Transvaal Republic, and manufactured at John Cockerill & Co., of Seraing. They were of the Vignoles type, weighing 56 lbs. per yard, and of the following

dimensions: Height, 3.9 inches; breadth of foot, 3.9 inches; breadth of head, 2.2 inches; thickness of web, 0.4 inch. Sixteen rails ware experimented on, and the tests and the results were as follows:

(A) The rail was to be placed on bearings 3 feet 7 inches, and receive a blow from a weight of 1,102 lbs., falling freely from a height of 19 feet 6 inches, without showing a set of more than 1.8 inch; and was then to be turned over and straightened back again under similar blows without breaking. The whole of the rails bore this test well, the largest set under the first blow being 2.1 inches. They were subsequently nicked in the foot, and then broken by blows of the same weight; the number of blows required varied from one to eight, the last number occurring with a rail which had been a long time under a hot sun, and may thus have been rendered more ductile.

(B) The rail, placed on the same bearings, was to support a weight of 9.8 tons at the center for five minutes without showing any permanent set; and subsequently a weight of 27.5 tons under the same conditions without breaking. The whole of the rails bore both these tests satisfactorily, the permanent sets in the second case varying from 1.97 to 4.9 inches.

(C) From each charge two small ingots were taken, and forged into bars 0.8 inch square, which when cold were bent double without breaking; the object of this test being to show that phosphorus, sulphur and silica were not present in an inordinate degree.

(D) Four pieces were cut off finished rails, forged into square bars, and then turned down to four different diameters, 0.59, 0.63, 0.61 and 0.73 inch respectively. These specimens, each 4 inches long, were then tested separately in a hydraulic press for tensional strength. The three first specimens behaved nearly alike, beginning to stretch sensibly at about 22.2 tons per square inch, and breaking at about 38 tons to the square inch, with a final extension of about 18.5 per cent., and contraction at the point of fracture of about 16 per cent. The fourth specimen began to lengthen at about 19 tons, and broke at 34.3 tons; but from the fracture it appeared to have been somewhat overheated, and thus not to give a fair test.

The above results show sufficiently the nature of the steel, which belonged to the category called in Belgium "Tres-tendre," or "Tendre," not capable of hardening in water. These qualities have from 0.18 to 0.20, and from 0.20 to 0.28 percentage of carbon respectively, and were used in this case on account of local circumstances, which did not allow of the quality "demi-dur," which is preferred in Europe. This quality has 0.28 to 0.30 percentage of carbon. The charge of raw material used by Messrs. Cockerill when making this steel is given in detail, and also its chemical composition when melted.

ENGINEERING STRUCTURES.

THE EMBANKMENT OF THE THAMES.—At the meeting of the Institution of Civil Engineers held on the 9th of April, the paper was on "The Embankment of the River Thames," by Mr. Edward Bazalgette, Assoc. Inst., C.E.

The River Thames was the arterial drain for 5264 square miles. Its source in Gloucestershire was 330 feet above the main level of the sea. It traversed 210 miles, and was tidal to Teddington Lock. In dry weather the discharge was about 470 million gallons daily. Its waters had been prevented from overflowing large tracts of land by embankments formed under various Acts of Parliament. The removal of Old London, Westminster, and Blackfriars Bridges, had enabled the tide to ebb and flow more freely by which the navigable channel had been deepened. The width of the river was, however, still very variable. Above Southwark Bridge it was 670 feet wide, and the waterway between the piers of that bridge was only 600 feet. At Hungerford Bridge, before the formation of the Victoria Embankment, the width was 1340 feet, whilst opposite Millbank it was only 610 feet, increased to nearly double that width at Battersea. Mud banks had formed along the foreshore, and between Westminster and Blackfriars about 27 acres of mud were exposed at low water on the north side.

The first commissioners for embanking the Thames were appointed in 1367. Acts for constructing embankments and improving the navigation were passed in the reigns of Henry VIII. and of Elizabeth. Sir Christopher Wren proposed an embankment from the Temple to the Tower after the fire of London in 1666. Sir Frederick Trench and Mr. Martin suggested similar embankments. In 1840 Mr. James Walker laid down a line for a northern embankment for the Corporation of London, to be raised 4 feet above Trinity high water. His line and levels had since been adopted. Various Parliamentary commissions and committees had considered the subject. In 1862, an Act was obtained by the Metropolitan Board of Works for the formation of the Victoria Embankment, from Westminster to Blackfriars Bridge. In 1863, another Act was passed for the construction of the Albert Embankment from Westminster to Vauxhall Bridge. And, lastly, in 1868 the Act for the Chelsea Embankment, from Chelsea Hospital to Battersea Bridge, was sanctioned. These embankments comprised about 3¼ miles of river wall, and had reclaimed 52 acres of land.

The length of the Victoria Embankment was about ¾ mile, and the area reclaimed was 37¼ acres. The roadway was 100 feet wide from Westminster to Blackfriars Bridge and was continued all the way from thence to the Mansion House of a width of 70 feet. The cost of the embankment had been £1,200,000 besides £450,000 paid for the purchase of property. The tides now rose higher than in former years. On the 15th of November, 1875, the tide was 17 feet one inch, and in January, 1877 it was 16 feet 6 inches above datum. This had been attributed to the formation of the embankments; but it was ascertained that the cause was chiefly due to the removal of the old bridges and of other obstructions. This embankment was formed with a sewer and a

subway for gas and water pipes in the retaining wall. The subway was 7 feet 6 inches in height and 9 feet in width, and the sewer varied from 7 feet 9 inches to 8 feet 3 inches in diameter. The batter of the wall was slightly curved, and the wall was faced with granite, fine axed, up to high-water mark, and moulded above that level. There were steamboat piers and landing places at various points. The Metropolitan District Railway had been constructed along the whole of this embankment, the level of the rails being 17½ feet below the surface of the roadway, which was suported by iron girders. The foundations of the embankment varied in depth with the nature of the ground, but were 32½ feet below Trinity high water. They were formed partly behind whole-tide timber dams driven into the clay as previously described by Mr. Ridley (Minutes of Proceedings of the Institution of Civil Engineers, vol. xxxi., page 3), and partly behind wrought-iron caissons, the caissons being used in bad ground, and near to the bridges and around the landing piers. The clay was reached at about 28 feet below Ordnance datum, but near Westminster bridge it was 32 feet deep. The level of the foreshore sloped from 6 feet above to 7 feet below datum. The foundations were carried down to 20 feet below datum; they rested mostly on the clay, and were formed of Portland cement concrete up to 12½ feet below datum, at which level the brickwork commenced. The bottom portions of the iron caisson coffer-dams were filled with concrete, and left in the ground permanently, and the piles of the wooden cofferdams were cut off under water at various levels, in both cases to protect the toe of the wall. The upper portions of the caissons were in half rings, and were capable of being used several times. When bolted together these rings formed an oval of 12 feet 6 inches in length by 7 feet wide in the center. The rings were 7 feet 6 inches deep, and were made of ¾ inch and ½ inch wrought-iron plates. The lowest ring of each caisson was of cast iron, weighing about 32 cwt., and it had a cutting edge at the bottom. The caissons were bolted together longitudinally, and strips of felt rendered the joints watertight. These dams, like the timber dams, were supported by timber shoring from the land side, and the upper portions of the dams consisted of half caissons only, by which a considerable saving was effected. In each caisson there was a sluice, worked from the top, for admitting or discharging the tidal waters. The caissons were sunk by weighting them, and excavating within them by three methods: 1. By men working inside, the water being kept down by pumping; 2, by men working within, the water being excluded by pneumatic pressure; and 3, by a telescopic dredger, the water being allowed to rise and fall within the cylinders. By the first plan 6 cubic yards, by the second 5.31 cubic yards, and by the third ten cubic yards of material were excavated per diem. Again, according to the first system, a cylinder was sunk on an average in eight days and a third, and the labor cost 14s. 6d. per cubic yard. By the second, a cylinder was sunk 20 feet in eleven days and a half, and the labor cost 12s. per cubic yard. By the third, a cylinder was sunk in less time at a cost of 8s. per cubic yard for labor.

The Albert Embankment was about 4300 feet long, and was similar in elevation to the Victoria Embankment. It had, however, neither sewer nor subway behind it. The foundations were carried to a depth of 30 feet below Trinity high water, and the wall was formed behind a whole tide timber dam, partly of single piles closely driven and caulked. Opposite Millbank the river had been widened for a length of 800 feet from 600 feet to 720 feet. Good foundations for this embankment were more easily reached than on the other side. Part of the embankment wall was formed of concrete instead of brickwork and the whole was faced with granite. The works cost £309,000.

The Chelsea Embankment was commenced in July, 1871 and completed May, 1874. It extended from Battersea Bridge to Chelsea Hospital, and was upwards of three quarters of a mile in length. The wall was composed of Portland cement concrete, faced with hammer dressed granite. It had a sewer from 5 feet 9 inches to 6 feet 9 inches in diameter behind it, conveying the sewage from Hammersmith to the Western Pumping Station. It had reduced the width of the river from 850 feet to 700 feet, and had reclaimed 9½ acres of foreshore. The roadway was 70 feet wide, and 5 feet above Trinity high water. The foundations were carried to 10 feet below Ordnance datum, or 4 feet under low-water spring tides, and they were put in behind a half-tide dam. A trench was dredged and concrete blocks were bedded upon the ground at low water up to 3 feet 3 inches below datum Above this level the concrete was filled in and bonded with the granite facing. The cost of this work, including the low-level sewer and roadway, was £134,000. The introduction of concrete in lieu of brickwork had effected a saving of of about £21,000. A short length of this embankment, opposite Cadogan Pier, settled in consequence of the removal of some piles, which formed part of the old pier, in front of it. The wall had since been underpinned from the land side, and its toe protected by sheet piling.

ORDNANCE AND NAVAL.

STEEL SHIPS.—On the 19th inst., a trial trip of a new steel vessel, the first built on the Tyne or elsewhere for ordinary sea going purposes, took place, and was completely successful. The vessel, which is named the Ethel, has been built by Messrs. C. Mitchell & Co., iron shipbuilders, Low Walker, to the order of Messrs. Henry Clapham & Co., merchants, Newcastle-upon-Tyne, and is intended for the Spanish ore trade. The length of the vessel is 210 feet between perpendiculars, and 216 feet over all; she is 30 feet beam, and 17 feet 3 inch depth moulded, or about 16 3/16 depth of hold. She is guaranteed by the builders to carry 1,300 tons on 14 feet 7 inch draught of water. The hull of the vessel in iron was estimated to weigh 450 tons; the stem, stern post,

bed-plate of engines, etc., and engine room are of iron, and are estimated to weigh 90 tons, which, deducted from the figures above given, leaves the weight of the hull at 360 tons. For this steel has been substituted; and Lloyd's have allowed on the average about 20 per cent. off the scantling, showing a saving of about 73 tons in weight of the hull. This necessitated the providing of 73 tons extra water ballast, which has been effected by an arrangement in the engine room. The total water ballast is 250 tons. The class of the vessel is ninety-five years A1. The engines have been built by the Wallsend Slipway Company. Both ship and boilers are built of Landore-Siemens steel. As regards the boilers, Lloyd's have allowed 21 per cent. off the outer shell, and 10 per cent. off the weight of the internal parts. The boilers are fitted with weldless steel tubes. At these reduetions of thickness the builders are confident that the vessel is stronger than if built in the ordinary way of irron. The material has shown an extraordinary toughness, and also great uniformity of quality. The breaking strain of the plates has been found, after very exhaustive tests, to be as follows:

No.	Elongation. Per cent.	Broke at tons to the square inch.
2	28 0	33
3	26.5	32½
4	26.5	32¼
9	25.0	32¼
10	28.4	32½
11	25.0	32¾
	6)154.4	6)195¼
Average	25.73	32½

The cost of the vessel has been about 8 per cent. more than if she had been built of iron. The other novelties introduced into the vessel are Sir Wm. Thomson's improved sounding machine, and Sir Wm. Thomson's improved mariners' compass. The chief objects aimed at in the latter are greater steadiness of the compass at sea in all weathers and in every class of ship; to reduce the fractional error to as small an amount as to cause no inaccuracy or inconvenience; to obtain greater security in the use of the compass in iron ships; and to diminish the expenses and annul the detentions at present required for adjusting compasses in iron ships. The sounding machine is designed for ascertaining accurately and quickly the the depth of water under a ship, without stopping or even reducing her speed; and on test proved accurate to half a fathom in nineteen — *Engineering.*

BOOK NOTICES.

INDEX CATALOGUE OF BOOKS AND MEMOIRS RELATING TO NEBULÆ, CLUSTERS, ETC. By EDWARD S. HOLDEN. Washington: Smithsonian Institute.

Indispensable to practical observers who work in this field. The catalogue contains 110 pages closely printed.

THE MONTHLY WEATHER REPORTS for March and April have come to hand since our last issue. The recent extension of the service of this department to include the Pacific coast, gives a new interest to the monthly issues. We believe no records of scientific labor are studied so closely or profitably, nor with so much of national pride, as those of the Weather Bureau.

SECOND ANNUAL REPORT OF THE STATE SURVEY, 1878.

The report of the Commissioners is a brief statement of the work performed in 1877. The report of the Director, Mr. James T. Gardner, is appended, including two maps, indicating the recent progress of the work. The maps are somewhat rudely executed, but exhibit some important corrections to be made in the old maps.

PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS. London: printed by Wm. Clowes & Sons.

The following papers in separate pamphlets, have been lately received from Mr. James Forrest, Secretary of the Institution.

The works of the Bilbao Iron-Ore Company in the Province of Biscay, Spain. By Frederick Cadogan Barron, A. I. C. E.

Irrigation in the South of France. By George Wilson, M. I. C. E.

Progress of Steam Shipping during the last quarter of a century. By Alfred Holt, M.I.C.E.

The Encroachments of the Sea from Spurn Point to Flamboro Head. By Robert Pickwell, A. I. C. E.

As each of the above papers relates to an important branch of engineering, the value of these additions to scientific literature, emanating from such high sources, is not easily overstated.

ACADIAN GEOLOGY. The Geological Structure, Organic Remains, and Mineral Resources of Nova Scotia, New Brunswick, and Prince Edward Island. Third edition; with a Geological Map and numerous Illustrations. By J. W. DAWSON, F.R.S., F.G.S., Principal of McGill College. Pp. 818; royal 8vo, Cloth, $6.00. Montreal: Dawson Brothers. For sale by D. Van Nostrand. Price of Supplement, $1.25.

This third edition of Dr. Dawson's important work is brought down to the most recent date by a Supplement containing all that has been discovered or established, since the publication of the second edition, concerning the Geological Structure; Fossil Remains and Mineral Resources of the Eastern Provinces. The work from the extent of its scope and the fulness of its detail is absolutely necessary to every one who may be interested in the devel opment of the resources of these Provinces. The map is colored geologically, and there are besides in the book over 400 illustrations. The labors of a life time of scientific research have been expended upon the elucidation of the Geology of these most interesting Provinces, and the results have been embodied by Principal Dawson in this handsome volume now reaching to 818 pages of octavo. The Supplement may be had separately by purchasers of the previous edition.

HOUSE DRAINAGE AND WATER SERVICE. By JAMES C. BAYLES. New York: David Williams. For sale by D. Van Nostrand. Price $3.00.

The author of this valuable and opportune work, modestly says of it, that "it is only just to the professional reader to say that this book is not intended as a contribution to the literature of sanitary engineering. It takes up the subjects of drainage and water supply where the engineer commonly leaves them, and treats almost exclusively of subjects in which householders and those connected with the house-building trades, are directly and immediately interested."

We may add that all intelligent readers will regard the treatise as an indispensable supplement to the best works on sanitary engineering. It deserves, and we trust will receive a welcome from the large constituency who believe in modern sanitary reform in the dwelling house.

PROF. ROBERT H. THURSTON'S SCIENTIFIC ESSAYS.

On a new type of steam engine, theoretically capable of utilizing the full mechanical equivalent of heat-energy, and on some points in theory indicating its practicability. Reprinted from Franklin Institute Journal.

On a new method of Planning Researches, and of representing to the eye the results of combination of three or more elements in varying proportions.

A paper presented to the American association for the advancement of science. Salem: Printed at the Salem Press.

Abstract of the statement of the extent and character of the work of the United States Board appointed to test iron, steel, and other metals. From the papers of the American Association.

The Growth of the Steam Engine, New York: D. Appleton & Co.

All of Prof. Thurston's papers are concise and accurate, and whether historical or otherwise, always relate to the present needs of engineering science.

WORKS ON FOREST SCIENCE BY DR. BROWN.

HYDROLOGY OF SOUTH AFRICA; or Details of the former hydrographic condition of the Cape of Good Hope, and of causes of its present aridity, with suggestions of appropriate remedies for this aridity.

In which the desiccation of South Africa, from pre-Adamic times to the present day, is traced by indications supplied by geological formations, by the physical geography or general contour of the country, and by aborescent productions in the interior, with results confirmatory of the opinion that the appropriate remedies are irrigation, arboriculture, and an improved forest economy: or the erection of dams to prevent the escape of a portion of the rainfall to the sea—the abandonment or restriction of the burning of the herbage and bush in connection with pastoral and agricultural operations—the conservation and extension of existing forests—and the adoption of measures similar to the *reboisement* and *gazonnement* carried out in France, with a view to prevent the formation of torrents and the destruction of property occasioned by them.

REBOISEMENT IN FRANCE; or Records of the re-planting of the Alps, the Cevennes, and the Pyrenees with trees, herbage, and bush, with a view to arresting and preventing the destructive consequences of torrents.

In which are given, a *resume* of Surrel's study of Alpine torrents, and of the literature of France relative to Alpine torrents, and remedial measures which have been proposed for adoption to prevent the disastrous consequences following from them—translations of documents and enactments, showing what legislative and executive measures have been taken by the Government of France in connection with *reboisement* as a remedial application against destructive torrents—and details in regard to the past, present, and prospective aspects of the work.

FORESTS AND MOISTURE. Effects of forests on humidity of climate.

In which are given details of phenomena of vegetation on which the meteorological effects of forests affecting the humidity of climate depend—of the effects of forests on the humidity of the atmosphere, on the humidity of the ground, on marshes, on the moisture of a wide expanse of country, on the local rainfall, and on rivers—and of the correspondence between the distribution of the rainfall and of forests—the measure of correspondence between the distribution of the rainfall and that of forests—the distribution of the rainfall dependent on geographical position, determined by the contour of a country—the distribution of forests affected by the distribution of the rainfall—and the local effects of forests on the distribution of the rainfall within the forest district.

THE SCHOOLS OF FORESTRY IN EUROPE. A plea for the creation of a School of Forestry in Edinburgh.

WATER SUPPLY OF SOUTH AFRICA, and facilities for the storage of it.

Ready for the Press.

ARBORICULTURE IN SOUTH AFRICA; or Facilities for the planting of trees existing in different districts at the Cape of Good Hope, with reports on the natural history, culture, and exploitation of the trees which have been recommended for culture in the colony.

Preparing for the Press.

DRIFT SANDS. Report on the arrest of drift sands and the utilization of sand plains by sylviculture in France, Belgium, Germany, Russia, Hungary, and other lands, with a view to showing the practicability of arresting and utilizing drift sands and sand plains in South Africa.

MISCELLANEOUS.

THE revenue of the Suez Canal Company in 1877 amounted to £1,310,456. The corresponding revenue in 1876 was £1,198,999; and in 1875, £1,135,452. The company's revenue thus increased at a more rapid rate in 1877 than in 1876, notwithstanding that a reduction of 5d. per ton was made in the tolls in April, 1877.